FORAMINIFERAL ASSOCIATIONS AROUND NORTHERN GREAT BARRIER ISLAND, NEW ZEALAND

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Abstract. Census data on benthic foraminiferal tests in 60 seafloor sediment samples (high tide to 68 m depth; slightly brackish to normal marine) around northern Great Barrier Island, are analysed by cluster analysis. The faunal samples are grouped into eight associations. Characterising species of each association are found by calculating "association scores" for each species, based on its abundance, relative abundance, fidelity, persistence and dominance within each association. The foraminiferal associations are: A. *Ammonia beccarii/Elphidium excavatum* - intertidal and shallow subtidal, sheltered, slightly brackish environments, 0-5 m; B. *Quinqueloculina seminula/Miliolinella subrotundata* - shallow subtidal, moderately sheltered, gravelly sand, 2-17 m; C. *Elphidium charlottensis/Haynesina depressula* - shallow subtidal sand, 4-16 m; D. *Nonionella flemingi/Bolivina pseudoplicata* - muddy sediment in quiet inner shelf depths, 12-35 m; E. *Gaudryina convexa/Discorbis dimidiatus* - moderately exposed sand at 1-28 m; F. *Discorbis dimidiatus/Rosalina irregularis* - sand at 3-33 m in Rangiwhakaea Bay; G. *Gaudryina convexa/ Bulimina submarginata* - wide range of sediment types, at 23-58 m depths on the exposed coast; H. *Bulimina submarginata/Hanzawaia bertheloti* - fine sand at mid shelf depths, >50 m.

In the cluster analysis dendrogram, the first order division splits the slightly brackish association A off from the remaining normal salinity associations. The second order division splits the normal salinity faunas into an eastern, more diverse, more oceanic group (E-H) and a western, more neritic group (B-D). The third order divisions split the oceanic and neritic groups into associations, presumably determined by a combination of other environmental factors, such as substrate type, energy regime, light penetration. The dominant foraminiferal species are grouped by cluster analysis into seven species associations. These correlate quite closely with the sample associations, with only two species associations being prevalent in more than one sample association. Planktics comprise 15-20% of the foraminiferal fauna in exposed situations (25-70 m depth) on both sides of northern Great Barrier Island, but the planktic associations are distinctly different. On the northeast side, the planktics are diverse in size range and taxonomic composition and indicate shoreward movement and input from the oceanic plankton offshore. On the northwest side, the planktics are all small and of low taxonomic diversity, dominated by *Globigerina falconensis* and *G. quinqueloba,* typical of nearshore neritic plankton.

Knowledge of the ecological distribution of shallow-water benthic foraminifera (Protista, Protozoa) has applications in both modern and fossil environmental studies. An understanding of modern foraminiferal patterns can be used in interpreting fossil foraminiferal faunas and allow micropaleontologists to make relatively accurate assessments of paleodepth, paleosalinity and paleoenvironments, that are useful in paleogeographic reconstruction. Fossil shallow water benthic foraminiferal faunas are of special relevance to modern methods of determining rates of Quaternary uplift, changes in sealevels and climate, and in the study and quantification of Cenozoic cyclothems, sequence stratigraphy and geohistory analysis.

This study is the third part of a six part programme, designed to document the ecological distribution patterns of modern shallow water (brackish and inner shelf) foraminifera around

New Zealand. The programme consists of six quantitative studies - two in each of the northern, central and southern regions of New Zealand. In each region, one study area is in an enclosed, largely brackish harbour and estuary, and one study area is largely in normal salinity habitats, both enclosed and open water. This Great Barrier study is of normal salinity environments in

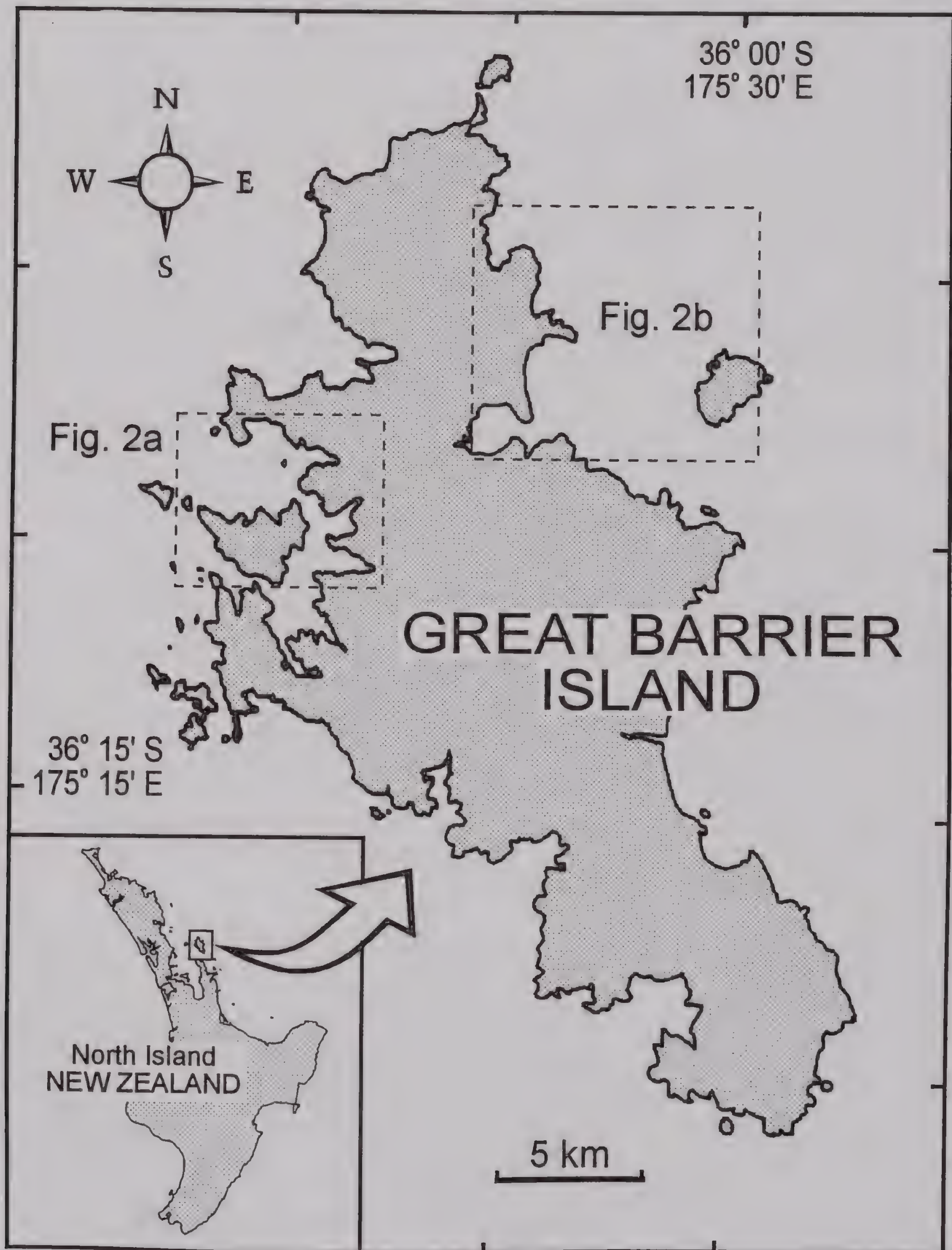


Fig. 1. Location map showing studied areas on Great Barrier Island.

the northern region. Studies completed so far are of normal salinity foraminifera in the south (Port Pegasus, Stewart Island - Hayward *et al.* 1994) and brackish harbour foraminifera in the central region (Pauatahanui Inlet - Hayward & Triggs 1994).

Other studies on New Zealand's shallow water foraminifera have documented their quantitative distribution in various normal salinity environments around the Cavalli Islands, eastern Bay of Islands and Chicken Islands (Hayward 1981, 1982a; Hayward *et al.* 1984), all 50-170 km northwest of Great Barrier Island. Lewis (1979) and Vella (1957) documented foraminiferal distribution in shelf and bathyal depths off the east and west coasts respectively of the southern North Island. Gregory (1973) described the intertidal foraminifera from a mangrove swamp at the head of Whangapara Harbour, southern Great Barrier Island.

This paper describes the benthic foraminiferal associations in 60 surface sediment samples from both sides of northern Great Barrier Island (latitude 36^{o} 10'S, longitude 175^{o} 20'E), New Zealand (Fig. 1). Twenty-four samples are from northwest Great Barrier - 11 from Port Abercrombie, 13 from Port Fitzroy; and 36 are from the northeast side between Rangiwhakaea Bay and Rakitu Island (Fig. 2, Appendix 1). The samples come from a broad range of inner and mid shelf environments (mid tide to 68 m depth) extending from sheltered, slightly brackish conditions at the head of arms in Port Fitzroy (stn. 21) through to normal salinity and exposure to the full force of the Pacific Ocean on the northeast coast of Great Barrier.

Port Abercrombie is a 3 km wide, 5 km long, semi-enclosed bay on the west coast of northern Great Barrier. It is 30-40 m deep except where it shallows steeply on the sides and more gradually at its head. Port Fitzroy is an elongate harbour (c. 7 x 2 km) enclosed by several peninsulas and Kaikoura Island. It is connected to the open sea via two narrow passages - Man of War Passage in the southwest and Fitzroy Passage in the north, which opens into Port Abercrombie. Most of Port Fitzroy is 15-30 m deep, though it shallows eastwards into its four narrow arms, each of which has extensive intertidal flats at their head. Considerable freshwater runoff flows via streams into the head of each of these arms especially after heavy rain, and lowers the salinity in the shallower surface water layers (Hickman 1979). Ports Fitzroy and Abercrombie are surrounded by moderately steep land, partly farmed, partly in kanuka scrub and partly in regenerating or mature native forest. The seasonal sea surface temperature range for these northwest ports is 13-23^{o}C (Hickman 1979).

The east side of northern Great Barrier is less embayed than the west side and is exposed to northeast swells from the Pacific Ocean. Rangiwhakaea Bay, where some of the sampling was undertaken, is a small bay 1.5 km across, open to the northeast and mostly shallower than 20 m. Rakitu Island, 2.5 km in diameter, lies 3 km offshore and provides some shelter to parts of this coast. A small enclosed cove (200 x 400 m) on the north coast of Rakitu Island provides the most sheltered environment sampled on this coast. The seafloor off northeast Great Barrier slopes gently seaward reaching 60 m depth, 2-3 km offshore.

SEDIMENTS

Grain size terminology follows Folk (1968). Sediment types at dredge stations are listed in Appendix 1, and their distribution shown in Fig. 3. The two areas studied have different environmental regimes with the Port Fitzroy/Port Abercrombie area being mostly a lower

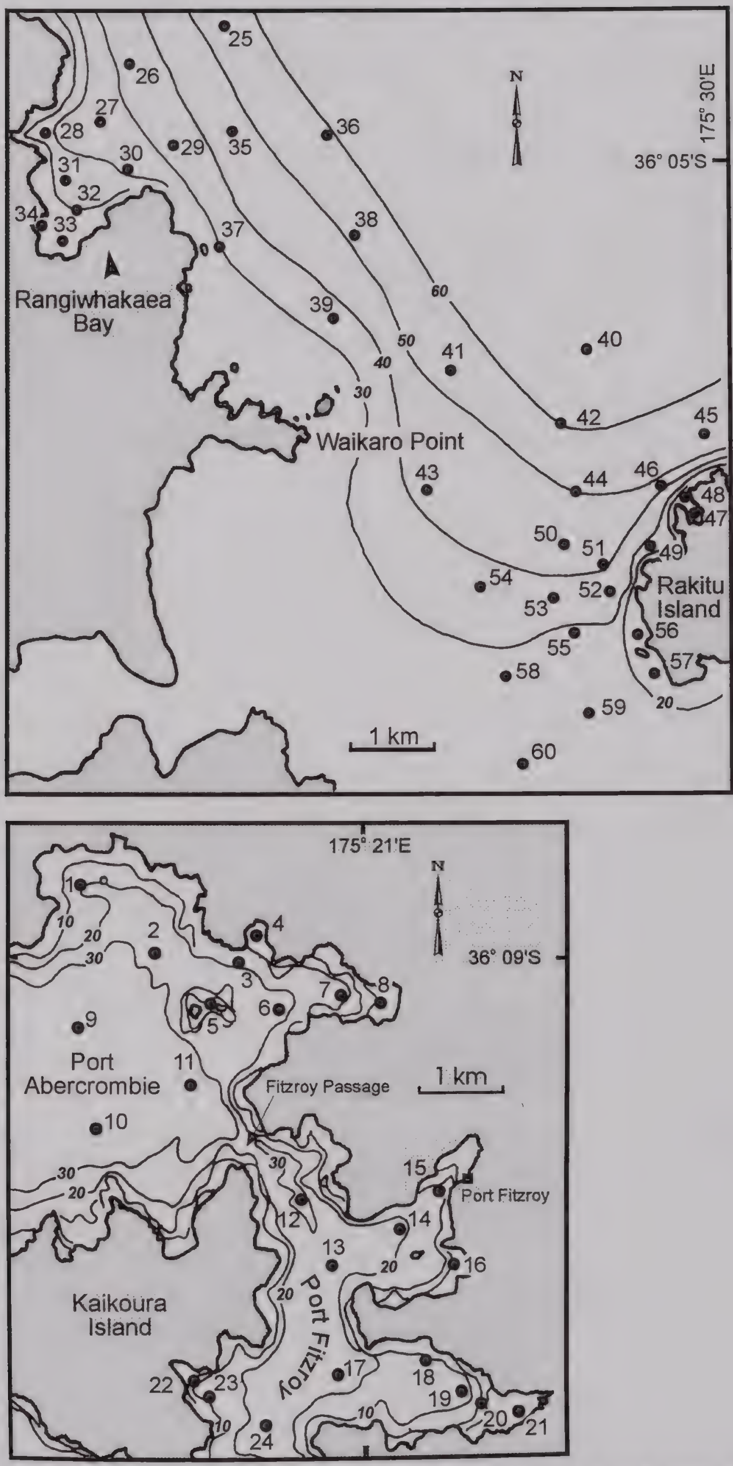


Fig. 2. Foraminiferal sediment sample locations and depth contours in Port Fitzroy and Port Abercrombie (below) and off northeastern Great Barrier Island (above).

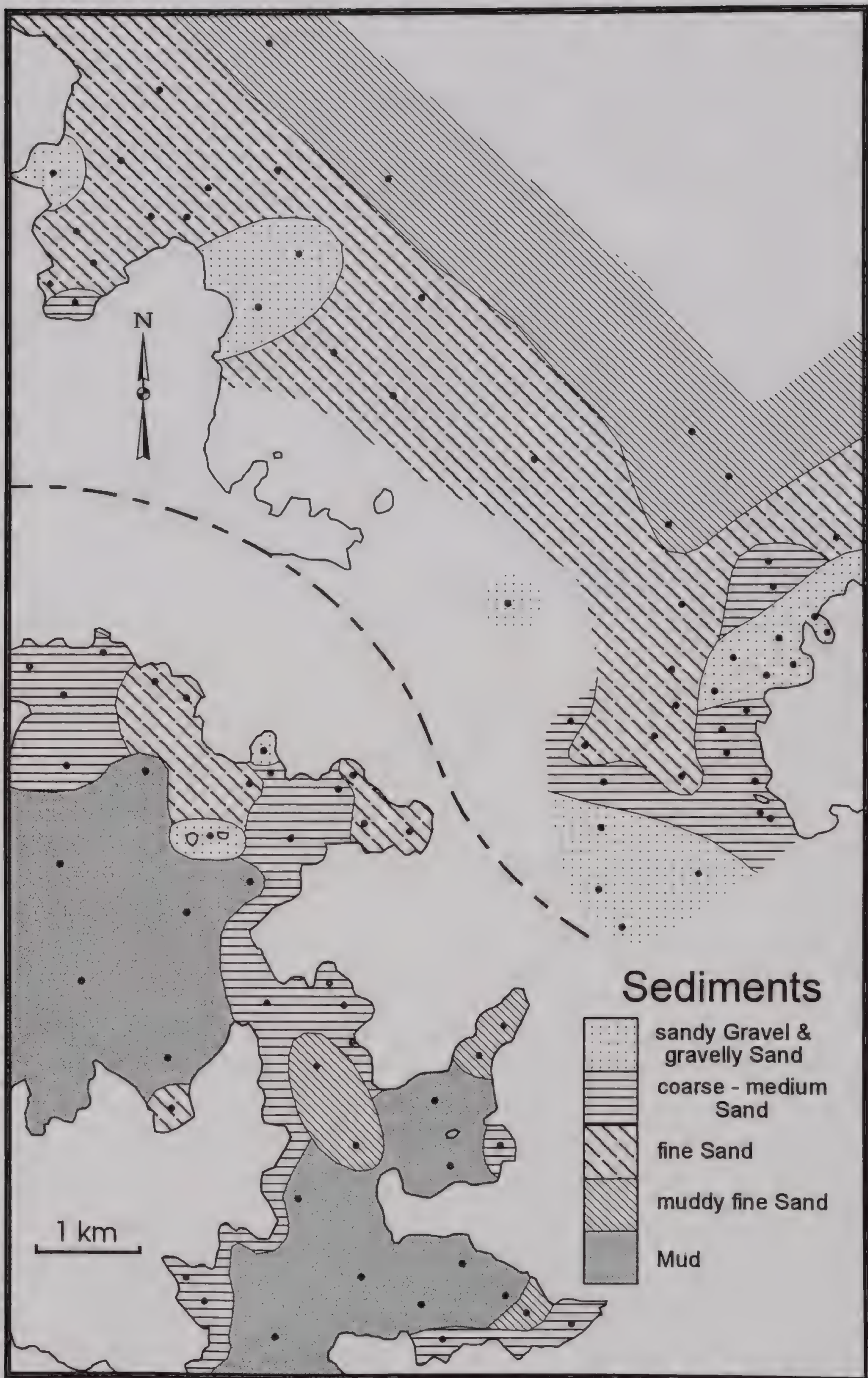


Fig. 3. Simplified sediment distribution maps of the two study areas, northern Great Barrier Island.

energy, sheltered, enclosed harbour, whereas the northeast area is largely a high energy, open marine situation. The coast of the Port Fitzroy/Port Abercrombie area is mostly rocky with small pocket beaches. The seafloor is predominately covered by muds. The deep, tidal Fitzroy Passage has medium and muddy fine sands. Areas of fine sand occur close to shore in the northern part of Port Abercrombie and in a small pocket in the south. Coarse and medium sands occur around the shoreline of both ports. Sandy gravel and gravelly sand are present only around small islands and off one pocket beach in northern Port Fitzroy.

Apart from the sandy shoreline south of Waikaro Point, the coast of the northeast area is rocky with small pocket beaches. The dominant sediments are a wide offshore strip of muddy fine and fine sand which extends into Rangiwhakaea Bay and as a tongue down the west side of Rakitu Island. Areas of sandy gravel and gravelly sand are present immediately offshore in the Rangiwhakaea Bay area, around the northwest coast of Rakitu Island and to the southwest of the island. A large area of coarse and medium sand occurs from the southwest coast of Rakitu Island westward. Pockets also occur in deep water (55 m) just northwest of Rakitu Island and inside Rangiwhakaea Bay.

SPECIMENS AND DATA

Faunas from northeast Great Barrier are deposited in the Micropaleontology Section of the Institute of Geological and Nuclear Sciences (samples F201848-201880; F202040-202066). Faunas from Port Fitzroy and Port Abercrombie are deposited in the Auckland Institute and Museum (L2803-2844). Figured specimens (Figs 4-32) are held by the Institute of Geological and Nuclear Sciences (catalogue numbers prefixed by FP). Copies of the raw data have been deposited with both the above institutions and is available on request.

METHODS

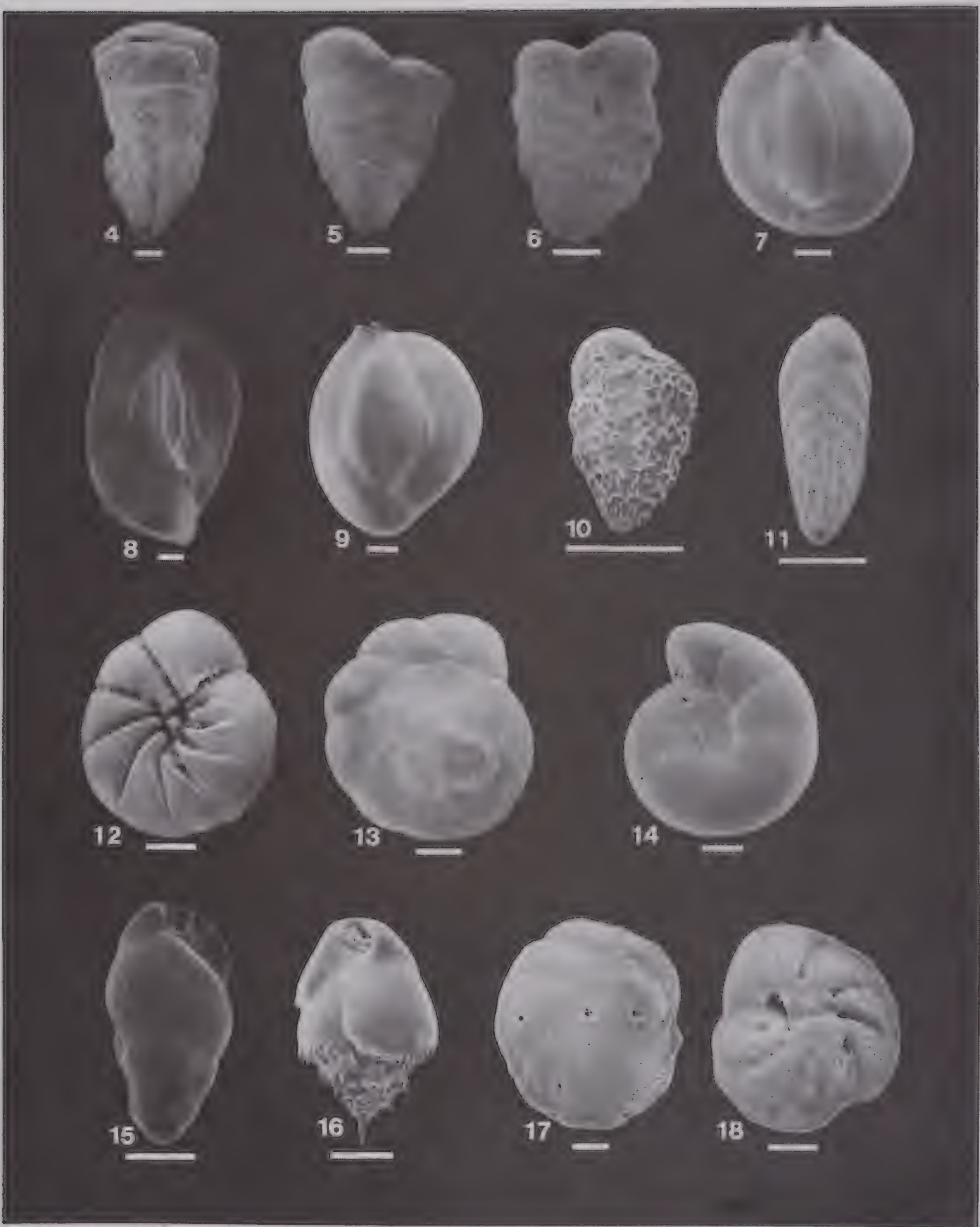
FIELD

Samples were collected using small, 4-10 litre capacity bucket dredges, hand-hauled from a 4 m aluminium dinghy powered by a 7 horse power outboard motor. The sea floor sediment was sampled to a depth of 50-100 mm. Sampling was undertaken during Offshore Islands Research Group trips to Rakitu Island in January 1981 and to Rangiwhakaea Bay in January 1983, and during an Auckland Museum trip to Port Fitzroy in February 1993.

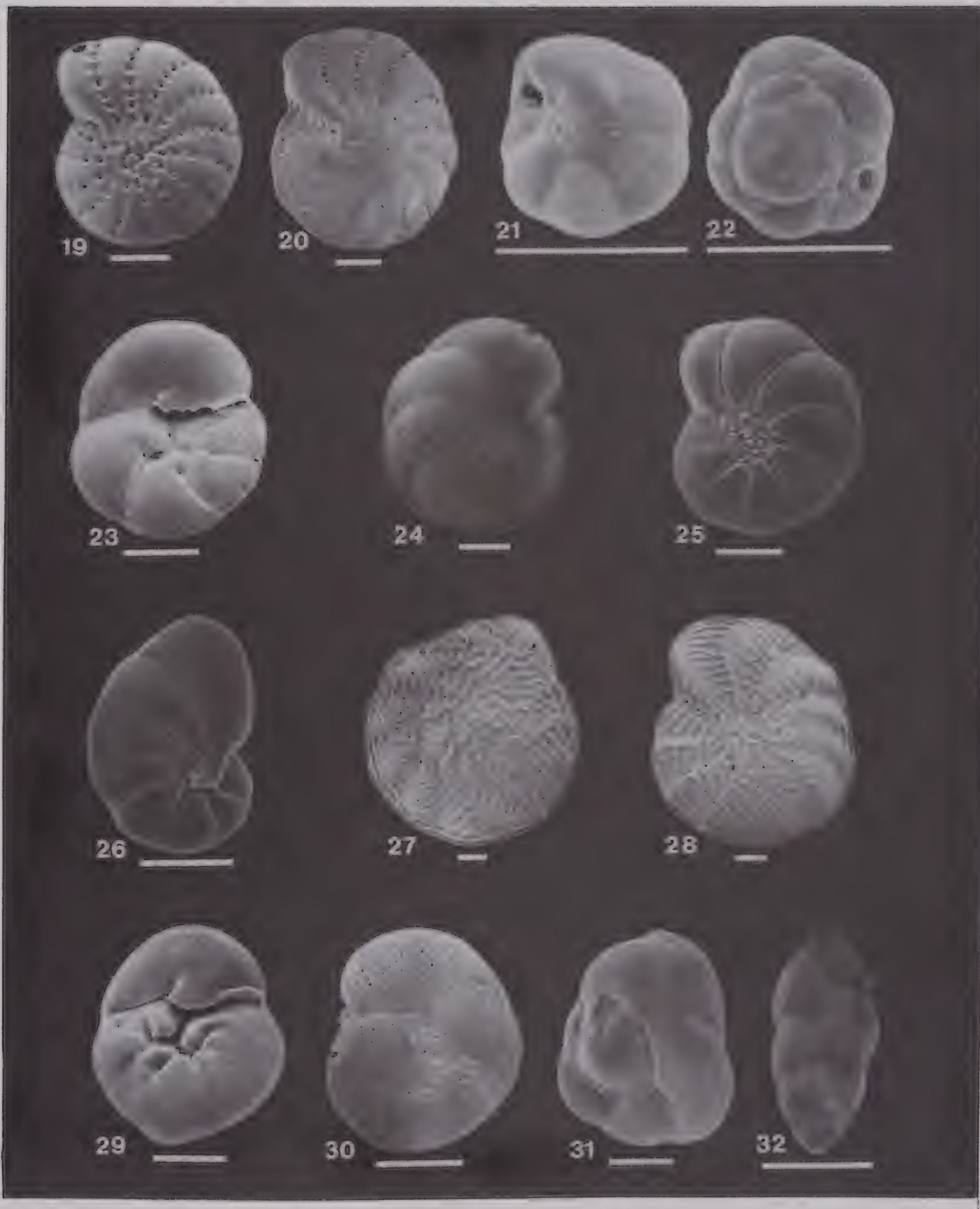
LABORATORY

Grain size analysis of each sample was by dry sieving (Folk 1968). The mud fraction (<0.06 mm) was washed away and foraminifera concentrated by floatation with carbon tetrachloride. The dried float from each sample was divided using a microsplitter until the quantity of material left contained approximately 100 benthic foraminifera which were then picked, mounted, identified and counted. Planktic foraminifera encountered during the benthic pick were identified and counted. The remaining unpicked float from a range of samples was subsequently quickly scanned and specimens of any additional rarer taxa were picked to give a more complete species list (Appendix 2).

In previous studies we have found that picking just 100 benthic foraminifera provides a



Figs 4-18. Scanning electron micrographs of characterising and more common foraminifera of northern Great Barrier Island. 4. *Gaudryina convexa*, Stn 58, FP4276. 5. *Textularia ensis*, Stn 51, FP4277. 6. *Textularia proxispira*, Stn 45, FP4278. 7. *Miliolinella subrotundata*, Stn 1, FP4279. 8. *Quinqueloculina colleenae*, Stn 1, FP4280. 9. *Quinqueloculina seminula*, Stn 1, FP4281. 10. *Bolivina pseudoplicata*, Stn 9, FP4282. 11. *Bolivina striatula*, Stn 9, FP4283. 12-13. *Ammonia beccarii*, Stn 8, FP4284-5. 14. *Anomalina spherica*, Stn 40, FP4286. 15. *Bulimina gibba*, Stn 47, FP4287. 16. *Bulimina submarginata*, Stn 40, FP4288. 17-18. *Discorbis dimidiatus*, Stn 34, FP4289-90. Scale bar 0.1 mm.



Figs 19-32. Scanning electron micrographs of characterising and more common foraminifera of northern Great Barrier Island. 19. *Elphidium excavatum*, Stn 21, FP4291. 20. *Elphidium charlottensis*, Stn 3, FP4292. 21-22. *Epistominella vitrea*, Stn 10, FP4293-4. 23. *Gavelinopsis lobulatus*, Stn 40, FP4295. 24. *Hanzawaia bertheloti*, Stn 40, FP4296. 25. *Haynesina depressula*, Stn 9, FP4297. 26. *Nonionella flemingi*, Stn 10, FP4298. 27-28. *Notorotalia olsoni*, Stn 9, FP4299-4300. 29-30. *Rosalina bradyi*, Stn 30, FP4301-4302. 31. *Rosalina irregularis*, Stn 27, FP4303. 32. *Siphouvigerina glabra,* Stn 19, FP4304. Scale bar 0.1 mm.

sufficiently accurate assessment of faunal composition for use in identifying and mapping associations. The computer programmes employed are primarily influenced by the dominants in each fauna and picks of 100 specimens readily identify these. The extra work in picking 200 or 300 benthics is unjustified in a study of this sort.

STATISTICAL

The data consist of counts of 195 species in 60 samples. The data matrix was standardised by converting counts to proportions of sample totals. Unweighted pair group cluster analysis using arithmetic averages of a Bray-Curtis distance matrix was used to produce a dendrogram classification of samples (Fig. 33) from which sample associations were selected. Similar cluster analysis of a distance matrix produced using Horn's (1966) modified version of Morista's (1959) index for proportions was used to produce a dendrogram classification of abundant species (>7% in any sample) from which species associations were selected (Fig. 34). Mathematical definitions of the Bray-Curtis and modified Morista coefficients are given in Sneath & Sokal (1973) and Rohlf (1989). The modified Morista index downweights the more abundant species and produces a more realistic clustering of species that commonly occur together. Cluster analyses were computed using the "NTSYS" statistical package (Rohlf 1989).

ASSOCIATION SCORES

To determine which species characterise each of the faunal associations, the more abundant taxa were ranked for each association using a value (association score) calculated to reflect their importance, based on a combination of five criteria (modified after McCloskey (1970) and Grange (1979)):

1. Dominance (Dom.). The 10 most abundant taxa of each station in an association were scored with most abundant species given a score of 10, the second most abundant a score of 9, and so on. The dominance of a taxon within an association is given by the mean score across all stations in that association.
2. Fidelity (Fid.), or degree to which a taxon is restricted to an association expressed as the proportion of stations within the association in which the taxon occurs less the proportion of stations outside the association in which it occurs.
3. Abundance (Abund.), given as the mean abundance of the taxon within the association.
4. Relative abundance (Rel.), expressed as the mean abundance of the taxon within the association less its mean abundance throughout all the stations.
5. Persistence (Pers.), given as the proportion of the stations within the association in which the taxon occurs.

The various criteria were weighted and combined to give an empirical association score for each species in each association, with a maximum value of 100 (Appendix 3). Association scores were calculated using the formula:
Assoc. Score = 4(0.3 Dom + 2 Fid + 0.11 Abund + 0.08 Rel + Pers).
Weightings have been assigned to each criterion to make their values more nearly equal, but giving greater weight to some criteria in the following decreasing order: Abundance, Relative abundance, Dominance, Fidelity, Persistence.

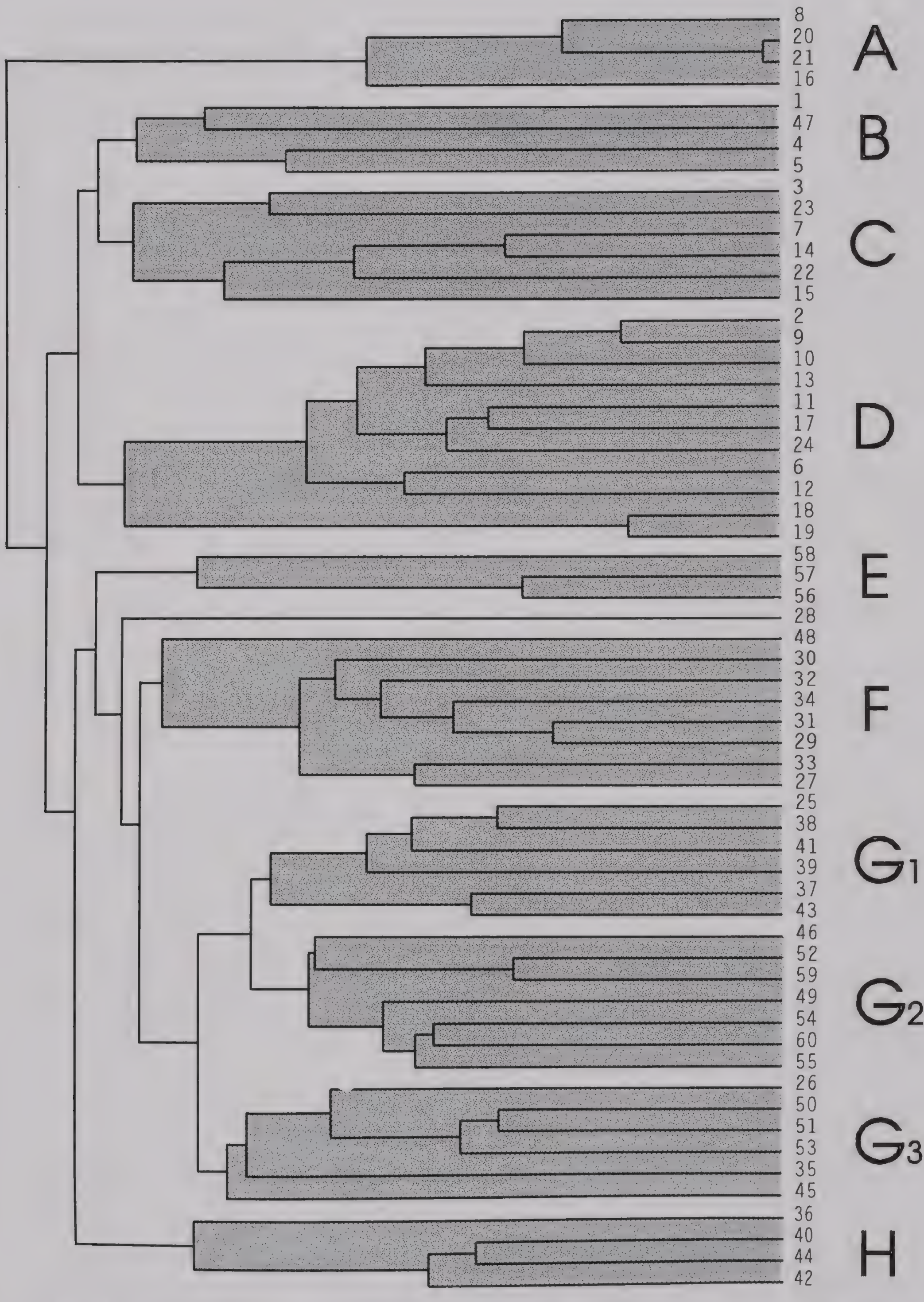


Fig. 33. Dendrogram classifications of northern Great Barrier Island foraminiferal samples produced by cluster analysis using Bray-Curtis distance matrix (Rohlf 1989). The eight sample associations (A-H) were selected by the authors, after inspection of the dendrograms.

SPECIES DIVERSITY

Species diversity was calculated for each fauna (Appendix 1), and also the mean values for each of the associations, using the following measure:
Shannon-Wiener Information Function, $H_{(S)} = \sum P_i \log_e P_i$,
where P_i is the proportion of the ith species (MacArthur & MacArthur (1961), Gibson and Buzas (1973)). Unlike the number of species (S) in a sample, the Information Function places little weight on rarer and very abundant species. The value of H depends on a combination of the evenness of species counts, together (to a lesser extent) with the number of species present.

SAMPLE ASSOCIATIONS

The following eight sample associations and three subassociations were selected by inspection from the cluster analysis dendrogram (Fig. 33) and their geographic distribution is shown in Fig. 35. The characterising species listed are those having the highest association scores (Appendix 3).

Association A ***Ammonia beccarii/Elphidium excavatum***
Stations : 8,16,20,21 = 4
Dominant species association : 1
Secondary species association : 2
Depth : mid tide-5.5 m
Sediment : muddy fine sand to gravelly coarse sand
Diversity : Information function H: 0.6-2.0, mean 1.3

This association occurs intertidally and in the shallow subtidal areas at the heads of the arms of Ports Abercrombie and Fitzroy. All localities are sheltered from all but minor wave exposure. Small streams empty into each of the arms and result in periodically lowered salinity in these stations, especially after heavy rain (Hickman 1979). The fauna is of low diversity and low equitability being dominated by *Ammonia beccarii* (mean abundance c. 60%) with the common subdominant *Elphidium excavatum* s.l. (mean abundance c. 15%). It has the lowest diversity of all the recognised associations in this study. This association is widespread throughout New Zealand and in other countries in sheltered and enclosed intertidal and shallow subtidal situations, often with slightly lowered salinity (Hayward & Hollis 1994).

Association B ***Quinqueloculina seminula/Miliolinella subrotundata***
Stations : 1,4,5,47 = 4
Dominant species association : 4
Depth : 2-17 m
Sediment : gravelly fine-medium sand to sandy gravel
Diversity : Information function H: 2.9-3.5, mean 3.2

This association occurs in gravelly sand and sandy gravel in shallow subtidal areas with normal salinity in moderately sheltered bays on the north side of Port Abercrombie and Rakitu Island and in the gravelly channel between two small islands in the middle of Port Abercrombie. The fauna is codominated by *Quinqueloculina seminula, Miliolinella subrotundata* and *Elphidium charlottensis* (each c. 8-10% mean abundance). *Bolivina pseudoplicata, Pileolina zelandica, Haynesina depressula* and *Notorotalia olsoni* (each c. 5-

6% mean abundance) are subdominant. *Q. seminula, M. subrotundata* and *P. zelandica* occur in their greatest abundances in this association. This association has many similarities to faunas recorded from shelly fine to medium sand at 4-10 m in the lee of Whale Island, Bay of Plenty (Hayward 1990) and to the *Elphidium charlottensis - Patelinella inconspicua - Quinqueloculina seminula* association that occurs at 0-10 m depth in the current-swept mouth and entrance channel of Pauatahanui inlet, Wellington (Hayward & Triggs 1994).

Association C ***Elphidium charlottensis/Haynesina depressula***
Stations : 3,7,14,15,22,23 = 6
Dominant species association : 2
Secondary species associations : 1,3
Depth : 4-16 m
Sediment : muddy fine sand to slightly gravelly medium-coarse sand
Diversity : Information function H: 1.9-3.0, mean 2.6

This association occurs in shallow subtidal sand around the fringes of Ports Abercrombie and Fitzroy. The fauna is codominated by *Elphidium charlottensis* and *Haynesina depressula* (each c. 16-18% mean abundance) with subdominant *Notorotalia olsoni, Ammonia beccarii* and *Quinqueloculina seminula* (each c. 5-8% mean abundance). *Bulimina gibba* and *Bolivina compacta* are other characterising species because of their high fidelity and relative abundance values. *E. charlottensis, H. depressula* and *N. olsoni* are significantly more abundant in this association than any other (Figs 34, 36). This association has previously been recognised along the east coast of Northland, in slightly gravelly fine sand at 2.5 m depth in Tutukaka Harbour (Brook *et al.* 1981) and in fine sand to sandy gravel at 0-6 m in sheltered bays of the Cavalli Islands (Hayward 1982a).

Association D ***Nonionella flemingi/Bolivina pseudoplicata***
Stations : 2,6,9,10,11,12,13,17,18,19,24 = 11
Dominant species association : 3
Secondary species association : 2
Depth : 12-35 m
Sediment : mud to slightly shelly muddy fine sand
Diversity : Information function H: 2.2-3.2, mean 2.7

This association occurs in fine-grained sediment in moderately quiet inner shelf areas at depths of 12-35 m in Ports Abercrombie and Fitzroy. The fauna is dominated by *Nonionella flemingi* (mean abundance c. 22%) with subdominant *Bolivina pseudoplicata, Elphidium charlottensis, Bulimina submarginata* and *Epistominella vitrea* (each c. 7-10% mean abundance). *Bolivina striatula* and *Siphouvigerina glabra* are also characterising species because of their high fidelity to this association. *N. flemingi, B. pseudoplicata* and *E. vitrea* (=species association 3) have their greatest abundances in this association (Figs 34, 37). A similar association, codominated by *Nonionella flemingi* but with more abundant *Notorotalia* and *Quinqueloculina finlayi,* has been described from identical sediment type in similar sheltered, deep, enclosed bays (22-30 m depth) at Port Pegasus, Stewart Island (Hayward *et al.* 1994) and has also been noted in similar environments in the Marlborough Sounds (Vella 1957).

Association E ***Gaudryina convexa/Discorbis dimidiatus***
Stations : 56,57,58 = 3

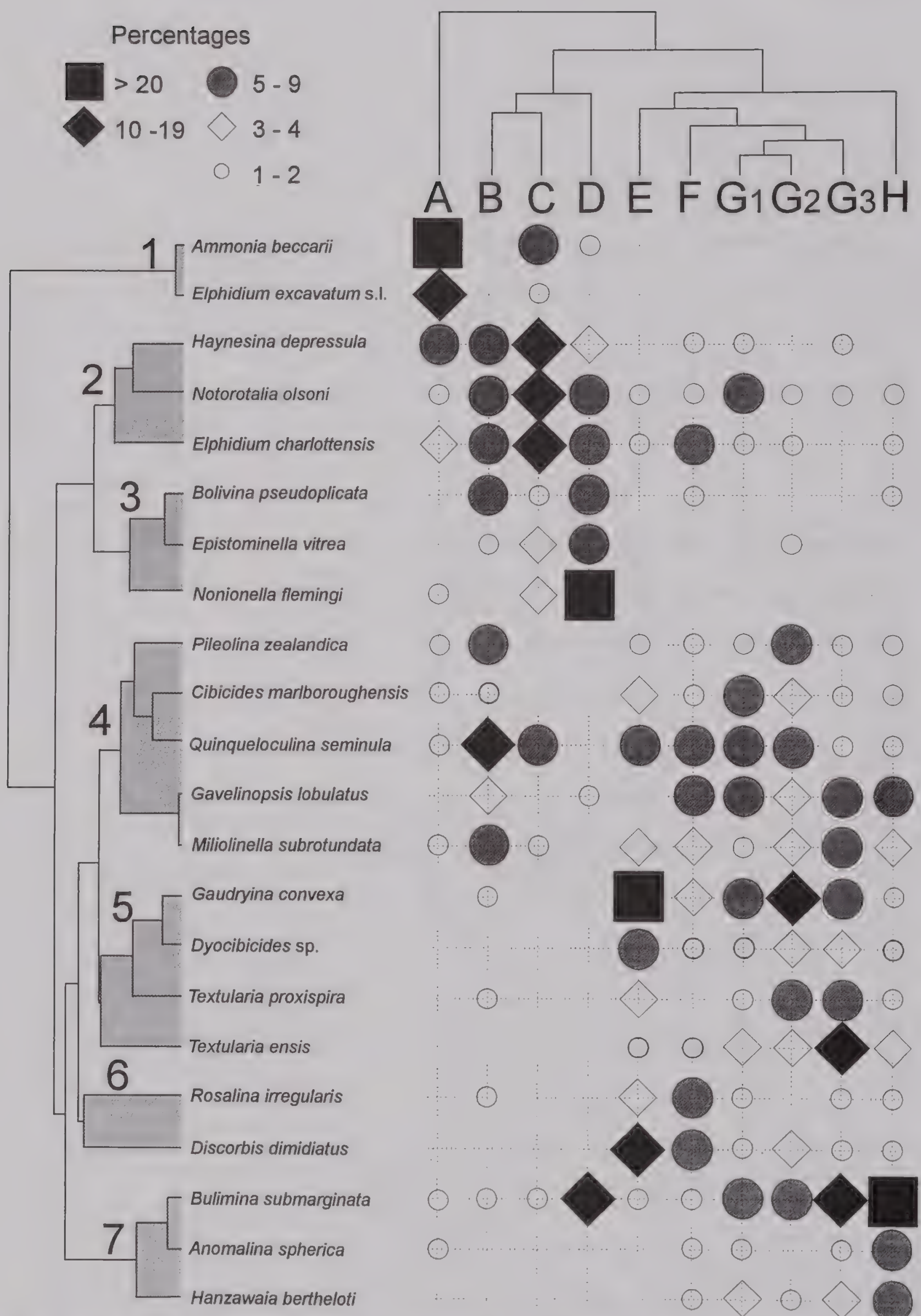


Fig. 34. Dendrogram classifications of northern Great Barrier Island foraminiferal associations (summarised after Fig. 33, top) produced by cluster analysis using Bray-Curtis distance, and of foraminiferal species (left) produced by cluster analysis using modified Morista distance (Rohlf 1989). The eight sample associations (A-H) and seven species associations (1-7) were selected by the authors, after inspection of the dendrograms. The relative abundance of each species in each sample is summarised in the chart.

Dominant species associations : 5,6
Secondary species association : 4
Depth : 1-28 m
Sediment : medium sand to slightly gravelly medium sand
Diversity : Information function H: 2.3-2.8, mean 2.6

This association occurs in medium sand close to the rocky shore of southwest Rakitu Island and in the channel between Rakitu and Great Barrier Islands. The fauna is dominated by *Gaudryina convexa* and *Discorbis dimidiatus* (mean abundances c. 23 and 16% respectively). *Quinqueloculina seminula* and *Dyocibicides* sp. are subdominant (each c. 7-8% mean abundance). *G. convexa, D. dimidiatus* and *Dyocibicides* sp. have their greatest abundances in this association (Figs 34, 38, 39). This association has a distinctly lower diversity than the surrounding association G. Similar associations to this have previously been recorded from a wide depth range from medium sand in exposed locations close to rocky islands along the east coast of northern New Zealand, at 2-28 m off the Cavalli Islands (Hayward 1982a) and at 6-37 m off Cuvier Island (Hayward & Grace 1981).

Association F ***Discorbis dimidiatus/Rosalina irregularis***
Stations : 27,29,30,31,32,33,34,48 = 8
Dominant species association : 6
Secondary species associations : 2,4
Depth : 3-33 m
Sediment : mostly fine sand, with minor gravelly coarse sand
Diversity : Information function H: 2.8-3.5, mean 3.3

This association is limited to and covers most of the floor of Rangiwhakaea Bay on the northeast side of Great Barrier Island. The fauna has high equitability with codominant *Discorbis dimidiatus, Rosalina irregularis, Elphidium charlottensis* and *Quinqueloculina seminula* (each c. 7% mean abundance). *Rosalina bradyi* and an undescribed glassy form of *Elphidium excavatum* are also characterising species because of their high fidelity values. *R. irregularis, R. bradyi* and *E. excavatum* new form have their greatest abundance in this association (Figs 34, 39). Associations similar to this, except for their greater abundance of *Pileolina zealandica,* have previously been recorded in fine to coarse sand in moderately exposed locations off east Northland at 5-35 m depth off the Chickens Islands (Hayward *et al.* 1984) and 4-10 m depth off Little Barrier Island (Hayward 1982b).

Association G ***Gaudryina convexa/Bulimina submarginata***
Stations : 25,26,35,37,38,39,41,43,45,46,49,50,51,52,53,54,55,59,60 = 19
Dominant species associations : 4,5,7
Depth : 23-58 m
Sediment : slightly muddy fine sand to coarse sandy pebble gravel
Diversity : Information function H: 2.7-3.5, mean 3.2

This association occurs in a wide range of sediment types in deeper inner shelf areas on the northeast side of Great Barrier Island. The fauna is a varied mix of species, codominated by *Gaudryina convexa* and *Bulimina submarginata* (mean abundance 7-8%) with subdominant *Textularia ensis, T. proxispira, Quinqueloculina seminula, Gavelinopsis lobatulus, Miliolinella subrotundata, Cibicides marlboroughensis* and *Dyocibicides* sp. (each c. 4-6%

mean abundance). The nineteen stations in this association can be divided into three subassociations using the cluster analysis (Fig. 33). *T. ensis, T. proxispira* and *C. marlboroughensis* have their greatest abundance in this association (Figs 34, 38).

Subassociation G1 ***Quinqueloculina seminula/Bulimina submarginata***
Stations : 25,37,38,39,41,43 = 6
Dominant species associations : 4,7
Secondary species association : 5
Depth : 30-56 m
Sediment : slightly muddy fine sand to gravelly very coarse sand
Diversity : Information function H: 3.1-3.4, mean 3.2

This subassociation generally occurs in deeper, more exposed parts of the area, shoreward of the deeper association H. The fauna is codominated by *Quinqueloculina seminula* and *Bulimina submarginata* (each c. 8% mean abundance). Subdominants include *Gavelinopsis lobatulus, Quinqueloculina parvaggluta, Cibicides marlboroughensis, Notorotalia olsoni, Hanzawaia bertheloti* and *Gaudryina convexa* (each c. 4-6%). Of these, only *C. marlboroughensis* has its greatest abundance in this subassociation (Fig. 34). This subassociation is similar to the *Cibicides marlboroughensis - Quinqueloculina seminula - Notorotalia olsoni* association (B3 of Hayward 1982a) that occurs in medium to very coarse sand at 4-40 m depth around the Cavalli Islands.

Subassociation G2 ***Gaudryina convexa/Textularia proxispira***
Stations : 46,49,52,54,55,59,60 = 7
Dominant species associations : 4,5
Depth : 23-51 m
Sediment : mostly gravelly coarse sand and coarse sandy pebble gravel, with minor fine and medium sand
Diversity : Information function H: 2.9-3.5, mean 3.2

This subassociation occurs in coarse sediments off the west coast of Rakitu Island and in the wide channel between Rakitu and Great Barrier Islands. The fauna is dominated by *Gaudryina convexa* (mean abundance c. 11%), with numerous subdominants - *Textularia proxispira, T. ensis, Quinqueloculina seminula, Pileolina zelandica, Dyocibicides* sp., *Cibicides marlboroughensis, Gavelinopsis lobatulus* and *Bulimina submarginata* (each c. 4-6% mean abundance).

Subassociation G3 ***Bulimina submarginata/Textularia ensis***
Stations : 26,35,45,50,51,53 = 6
Dominant species associations : 4,5,7
Depth : 34-58 m
Sediment : mostly slightly muddy fine sand, minor slightly muddy very coarse sand
Diversity : Information function H: 2.7-3.5, mean 3.1

This subassociation generally occurs in slightly muddy fine sand between subassociation G2 and association H off the west coast of Rakitu Island and between associations F and G1 across the entrance to Rangiwhakaea Bay. The fauna is codominated by *Bulimina submarginata* and *Textularia ensis* (each c. 11-13%) with subdominant *Miliolinella subrotundata, Gaudryina*

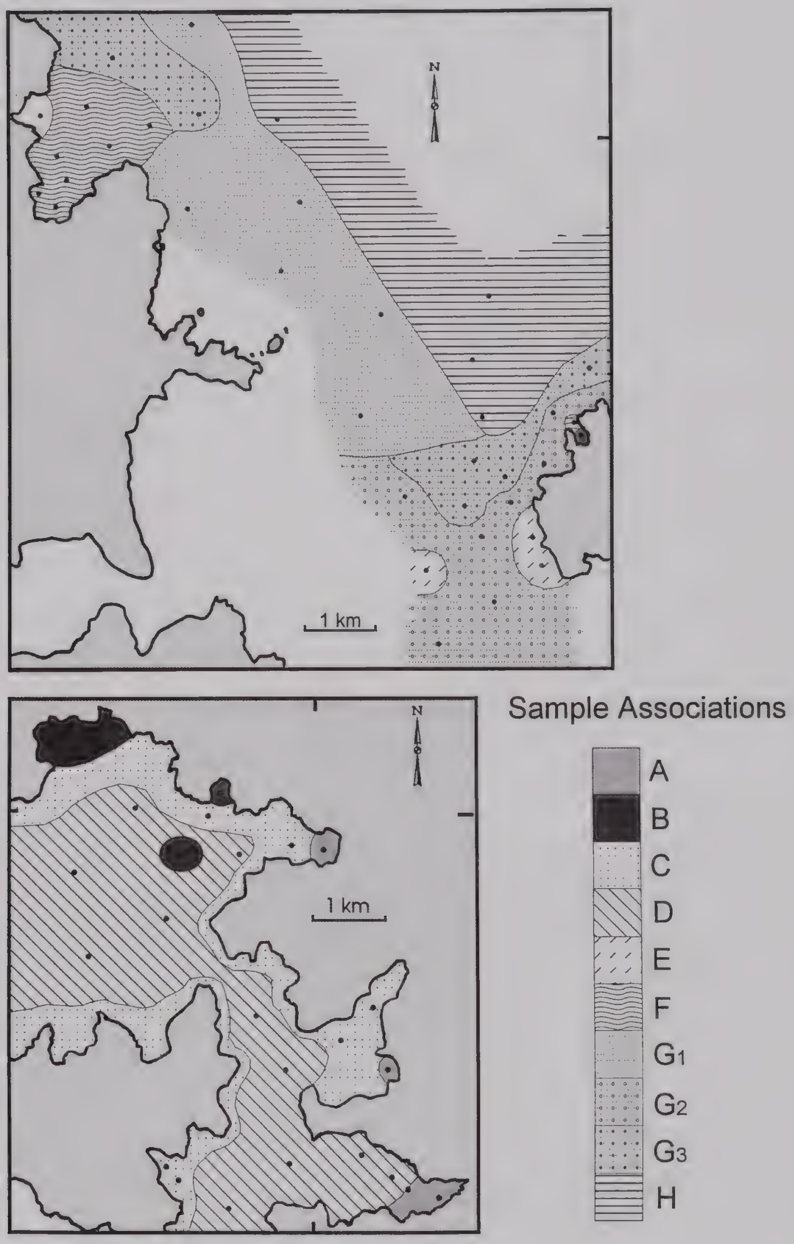


Fig. 35. Distribution of the eight benthic foraminiferal sample associations and three subassociations of northern Great Barrier Island. Association A = *Ammonia beccarii/Elphidium excavatum*, B = *Quinqueloculina seminula/Miliolinella subrotundata*, C = *Elphidium charlottensis/Haynesina depressula*, D = *Nonionella flemingi/Bolivina pseudoplicata*, E = *Gaudryina convexa/Discorbis dimidiatus*, F = *Discorbis dimidiatus/Rosalina irregularis*, G = *Gaudryina convexa/Bulimina submarginata*, subassociation G1 = *Quinqueloculina seminula/Bulimina submarginata*, G2 = *Gaudryina convexa/Textularia proxispira*, G3 = *Bulimina submarginata/Textularia ensis*, H = *Bulimina submarginata/Hanzawaia bertheloti*.

convexa, Textularia proxispira and *Gavelinopsis lobatulus* (each c. 5-7%). *T. ensis* and *T. proxispira* have their greatest abundances in this subassociation (Figs 34, 38).

Association H **_Bulimina submarginata/Hanzawaia bertheloti_**
Stations : 36,40,42,44 = 4
Dominant species association : 7
Depth : 50-68 m
Sediment : muddy fine sand to fine sand
Diversity : Information function H: 2.3-3.3, mean 2.8

This is the deepest water association. It occurs in fine sand at mid shelf depths (>50 m) off the northeast coast of Great Barrier Island. The fauna is dominated by *Bulimina submarginata* (c. 27% mean abundance) with subdominant *Hanzawaia bertheloti* and *Gavelinopsis lobatulus* (each c. 8-9% mean abundance). *Anomalina spherica* is characteristic of this association because of its high fidelity and relative abundance values. All these species occur in their greatest abundances in this association (Figs 34, 39). This association has a lower diversity than nearby associations F and G. It occurs in muddy fine sand at 50 m depth off the Chickens Islands (Hayward *et al.* 1984) and is similar to association D of Hayward (1982a) that occurs in similar fine sediment at 29-41 m depth off the Cavalli Islands. The Cavalli Islands fauna differs however in being codominated by *Cassidulina carinata* and *Globocassidulina canalisuturata,* both of which are rare in these Great Barrier samples.

Ungrouped sample
Station : 28
Depth : 19 m
Dominant species association : 4
Sediment : coarse sandy pebble gravel
Diversity : Information function H: 2.8

This station, in an arm of Rangiwhakaea Bay, has a fauna similar to association B, which occurs in similar locations around Port Abercrombie and Rakitu Island. The fauna differs from all others by its unusually high abundance of *Gavelinopsis lobatulus* (c. 29% mean abundance, Fig. 38).

SPECIES ASSOCIATIONS

The following seven species associations have been selected by inspection from the cluster analysis dendrogram (Fig. 34) generated using all species that occur as 7% or more in any one sample.

Association 1 (Fig. 36)
Species : *Ammonia becarrii, Elphidium excavatum* s.l.
Dominant sample association : A
Secondary sample association : C

Association 2 (Fig. 36)
Species : *Elphidium charlottensis, Haynesina depressula, Bulimina gibba, Notorotalia olsoni, Bolivina compacta*

Dominant sample association : C
Secondary sample associations : B,D

Association 3 (Fig. 37)
Species : *Nonionella flemingi, Bolivina pseudoplicata, Epistominella vitrea, Bolivina striatula, Siphouvigerina glabra*
Dominant sample association : D
Secondary sample association : C

Association 4 (Fig. 37)
Species : *Quinqueloculina seminula, Q. suborbicularis, Q. parvaggluta, Miliolinella subrotundata, Gavelinopsis lobatulus, Rosalina bradyi, Pileolina zelandica, Cibicides marlboroughensis, Oolina melo*
Dominant sample associations : B,G
Secondary sample association : E,F

Association 5 (Fig. 38)
Species : *Gaudryina convexa, Quinqueloculina colleenae, Dyocibicides* sp., *Textularia proxispira, T. ensis*
Dominant sample associations : E,G

Association 6 (Fig. 39)
Species : *Discorbis dimidiatus, Rosalina irregularis, Bolivina spathulata, Elphidium excavatum* n.f.
Dominant sample association : E,F

Association 7 (Fig. 39)
Species : *Bulimina submarginata, Hanzawaia bertheloti, Anomalina spherica*
Dominant sample association : H
Secondary sample associations : D,G

Ungrouped species
Species : *Miliolinella labiosa, Fissurina claricuta*

SPECIES DIVERSITY

The values for the Information Function, H, for each sample have been mapped and contoured in Fig. 40. This shows that the northeast side of Great Barrier Island has slightly higher overall values for species diversity than the northwest side. The lowest values in this study occur at the heads of the sheltered, slightly brackish bays on the east sides of Ports Fitzroy and Abercrombie (Associations A and 1). These values progressively increase moving out into the more open parts of the ports. There is an area in the entrance to Port Fitzroy with a slightly raised level of diversity, possibly produced by increased mixing and transport of tests into this area from outside by strong tidal currents. There are two areas in the northeast study area that have somewhat lowered diversity. These correspond to associations E and H, which have a greater abundance of the one or two dominant species than occurs in nearby associations F and G.

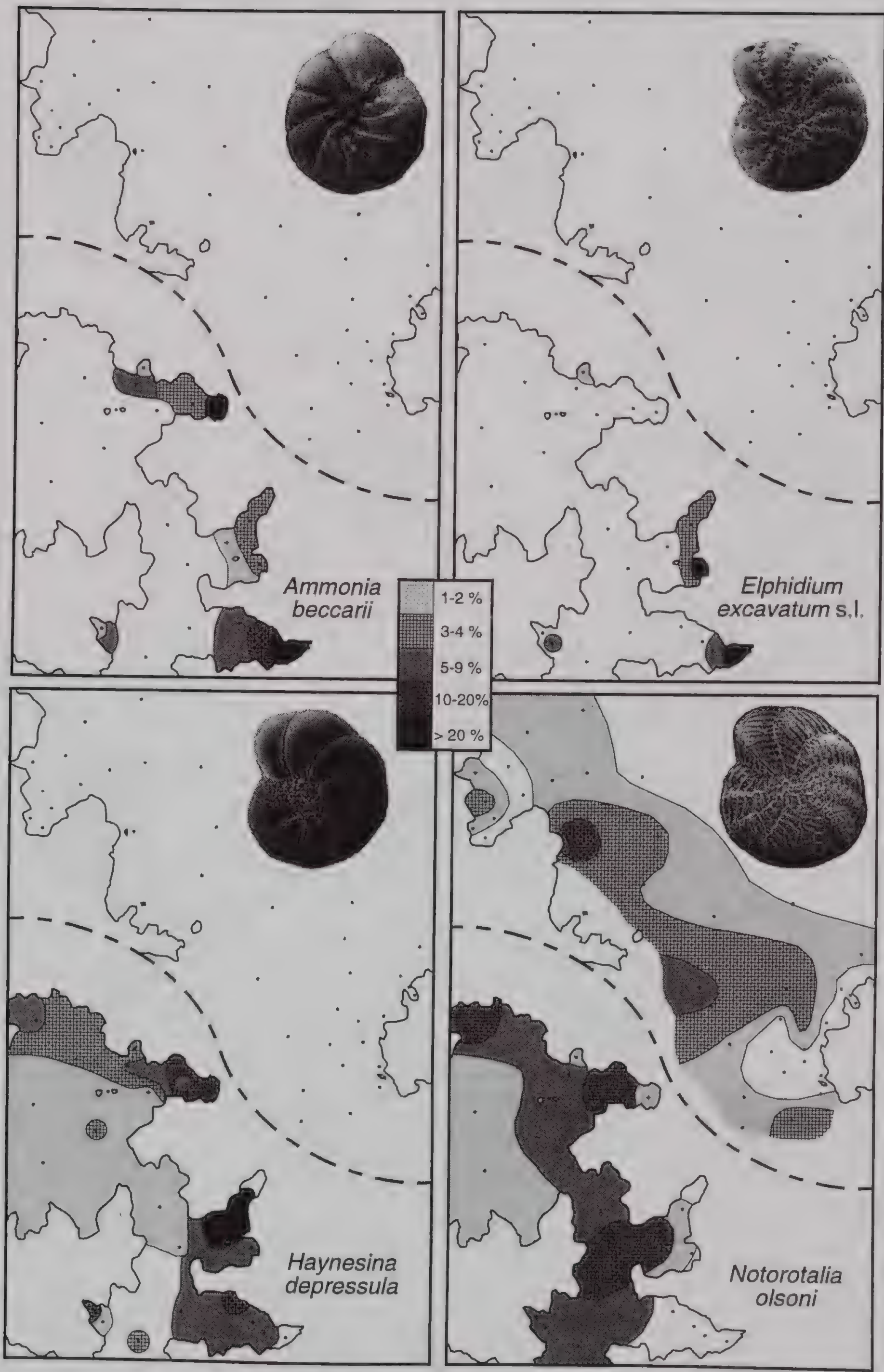


Fig. 36. Contoured abundance distribution maps of the dominant characterising species of species associations 1 and 2 of northern Great Barrier Island.

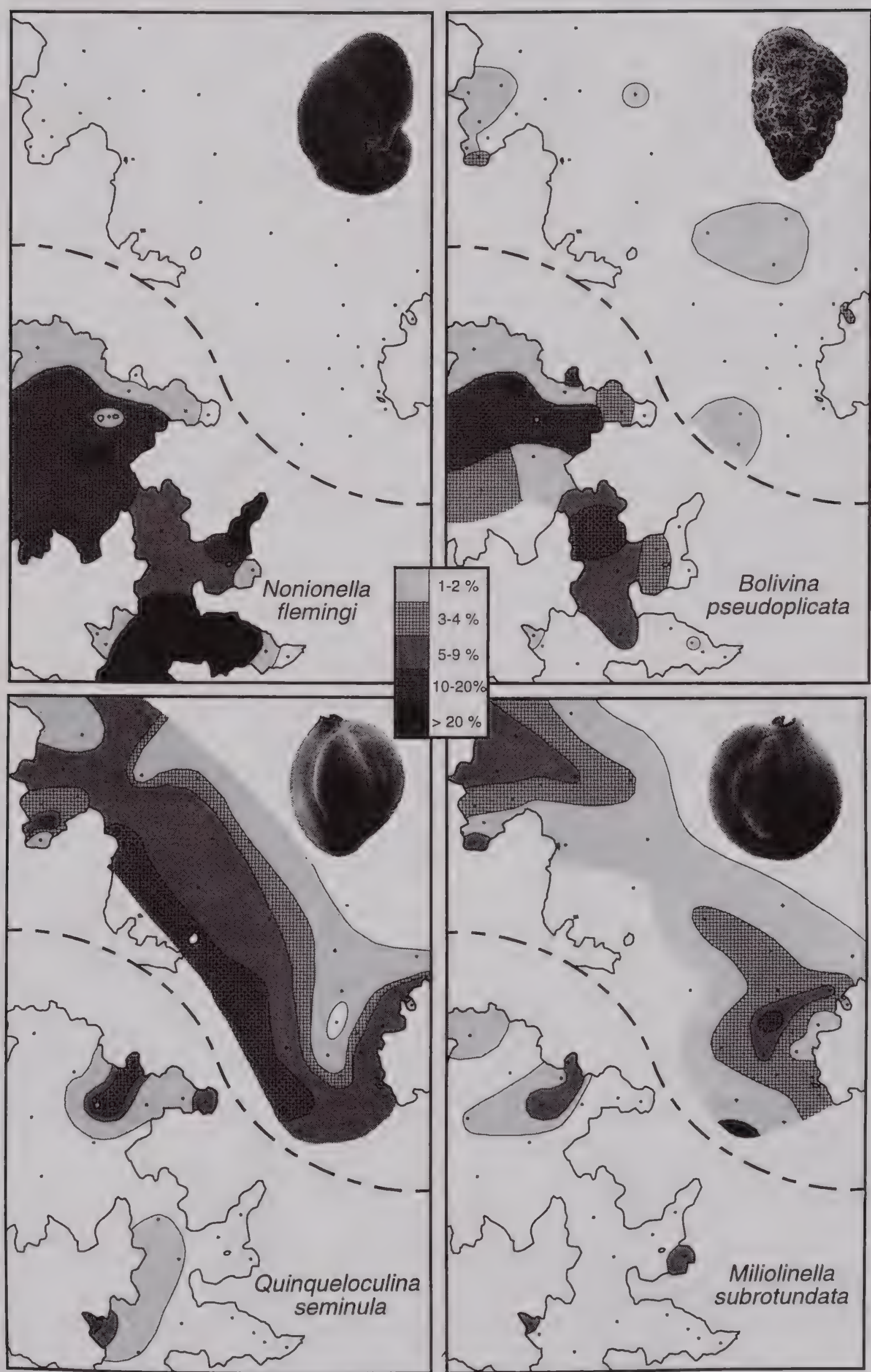


Fig. 37. Contoured abundance distribution maps of the dominant characterising species of species associations 3 and 4 of northern Great Barrier Island.

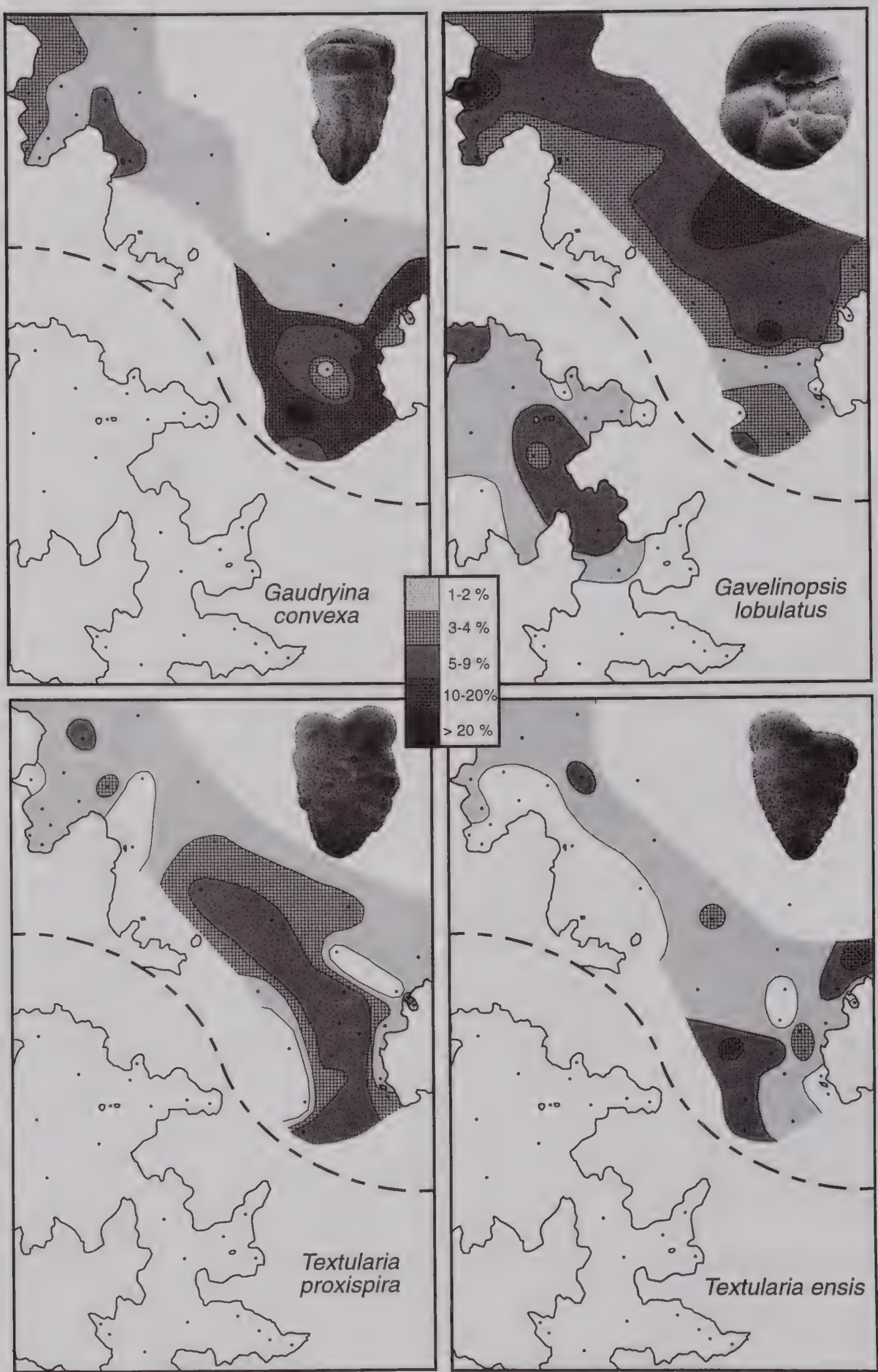


Fig. 38. Contoured abundance distribution maps of the dominant characterising species of species associations 4 and 5 of northern Great Barrier Island.

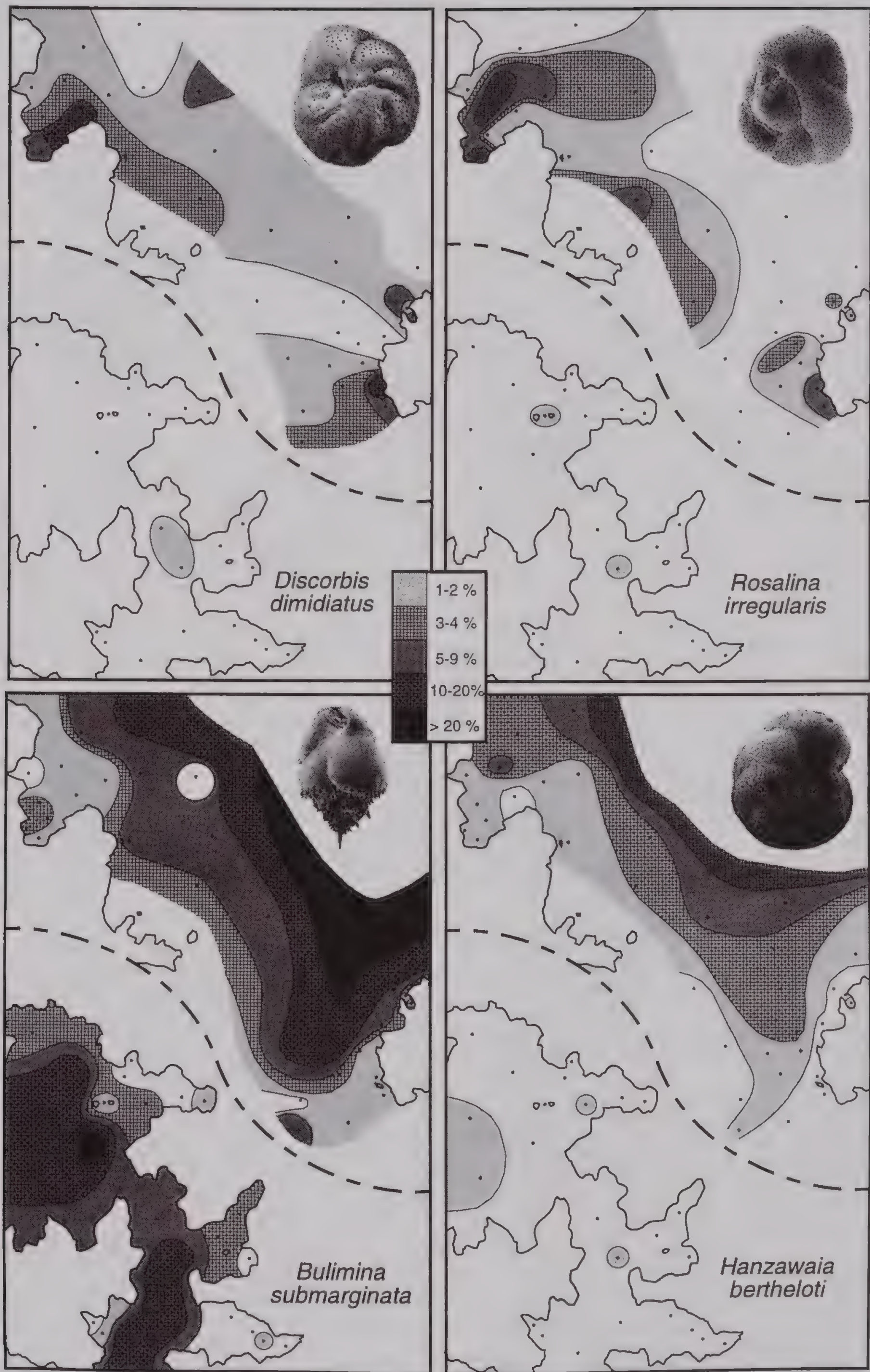


Fig. 39. Contoured abundance distribution maps of the dominant characterising species of species associations 6 and 7 of northern Great Barrier Island.

ARE THE SAMPLE AND SPECIES ASSOCIATIONS REAL?

There is remarkably close correspondence between the sample and species associations, with a direct one to one relationship between four of the species associations and four of the sample associations. These suggest that associations A and 1, C and 2, D and 3, and H and 7 are strong and robust and reflect real associations of species that inhabit mappably distinct environments.

The boundaries between associations B, E, F, G, 4, 5 and 6 are less clear and overlapping and the recognised associations are less strong. Examination of the individual distribution maps of the dominant species of these associations shows that only *Discorbis dimidiatus* and *Rosalina irregularis* (species association 6) have strongly coinciding distribution patterns and hence the other computer-generated associations are not strong. These associations occur in areas of coarsest sediments and strongest currents and swells, mostly off the northeast side of Great Barrier. Post-mortem transport of tests may be producing some mixing, but it appears that in this environment each of the common species has its own unique environmental requirements and thus its own individual distributional pattern which does not closely overlap with other common species to produce a recognisably recurring association.

We conclude that sample associations A, C, D and H and species associations 1, 2, 3, 6 and 7 are robust and real. The computer-generated grouping of the remaining samples and species into associations is less strong and somewhat forced within the present data set. This does not necessarily mean that usage of these groupings is not useful in helping to understand the ecological distribution patterns.

ENVIRONMENTAL FACTORS AND THE ASSOCIATIONS

SALINITY INFLUENCE

The most distinctive sample and species associations are the *Ammonia beccarii*/*Elphidium excavatum* associations (A and 1), as they split off from all others at the highest level of both dendrograms (Fig. 34). This association is characteristic of slightly brackish environments, whereas all other associations in this study are from normal salinity conditions.

WESTERN AND EASTERN ASSOCIATIONS

At the second highest level the sample dendrogram splits the normal salinity faunas into two groups (associations B, C and D, and associations E, F, G and H) which correspond closely to a split between northwest and northeast Great Barrier distribution. Only association B has samples from both sides of the island. The species dendrogram also splits the normal salinity species associations into northwest (associations 2 and 3) and northeast (associations 4, 5, 6 and 7) groups. In this instance, species association 4, which corresponds to sample association B, is grouped with the northeast group.

This distinct difference between the foraminiferal faunas from either side of northern Great Barrier Island is further illustrated by the distribution patterns of some of the dominant species. *Elphidium excavatum* s.l., *Ammonia beccarii, Nonionella flemingi, Bolivina striatula* and *Siphouvigerina glabra* occur almost exclusively on the northwest side and *Gaudryina* *convexa, Textularia proxispira, T. ensis, Rosalina irregularis, Discorbis dimidiatus, Anomalina spherica* and *Elphidium excavatum* n.f. occur almost exclusively on the northeast side. Only 50% of the total fauna in the quantitative counts occur on both sides of northern Great Barrier. The northeast side has a more diverse fauna (mean H = 3.1) with 87% of the taxa (169 species) recorded there, and 63% of the taxa found on the northwest side (mean H = 2.8). Other common species found only in the northwest include *Bulimina patagonica, Buliminella elegantissima,* and *Massilina* cf. *milletti;* and species only found in the northeast include *Miliolinella labiosa, Pyrgo* spp., *Spiroloculina disparilis, Triloculina* spp., *Cibicides corticatus, Ehrenbergina* spp., *Guttulina* spp., *Oridorsalis umbonatus* and *Siphouvigerina vadescens.*

The clear distinction between northwest and northeast associations probably relates to basic differences in the overlying water masses. The northeast area is more exposed to the open Pacific Ocean and receives clearer, more oceanic water influenced by the warm, east Northland current. The northwest area is more sheltered and receives more turbid, neritic water influenced by freshwater runoff into Ports Fitzroy and Abercrombie and by the circulating neritic waters of the Hauraki Gulf. The planktic foraminiferal compositional differences also reflect the more neritic character of the water in the west with a low diversity fauna and the greater oceanic influence in the east with greater diversity and size.

INFLUENCE OF THE EAST NORTHLAND CURRENT

The influence of the warm, subtropical east Northland current on northeast Great Barrier is manifest in the only known New Zealand occurrence of the tropical *Elphidium crispum,* plus occurrences of warm-water restricted species (Hayward 1980) such as *Elphidium excavatum* n.f., *Buliminoides williamsoniana, Textularia fistulosa, Cornuspira planorbis, Earltheeia clarionensis, Pileolina calcarata, P. harmeri, Nevillina coronata, Spiroloculina angulata, Carterina spiculotesta, Hanzawaia lepida, Heronallenia pulvinulinoides, Laticarinina coronata, Loxostomum limbatum costulatum* and *Rugidia simplex.*

INFLUENCE OF OTHER PHYSICAL ENVIRONMENTAL FACTORS

The third order of subdivision in the sample and species dendrograms (Fig. 34) is the level adopted for the recognition of sample and species associations. Within each of the northwest and northeast areas these associations appear to be determined by a combination of physical environmental factors, other than salinity and oceanicity.

The sediment analyses show some apparent correlation between grain size or mud content and some of the faunal associations. Associations D, H, 3 and 7 occur in fine muddy sediment, E occurs in medium sand and B in sandy gravel. The other associations and subassociations exist in an extremely wide range of sediment substrate types. Sediment grain size is in part related to the level of exposure to high wave and current energy. Thus associations D, H, 3 and 7 with the finest sediments also occur in the areas most sheltered from strong wave and current energy. Associations C and 2 are subject to moderate levels of environmental energy, whereas associations B, E, F, G, 4 , 5 and 6 are subject to the greatest wave and current activity in the study area.

Sample associations E and F and species association 6 are specialised associations dominated by epifaunal species that attach to rock, pebbles or shells and drop off into the sediment on death. The influence of other factors related to depth on the distribution of the

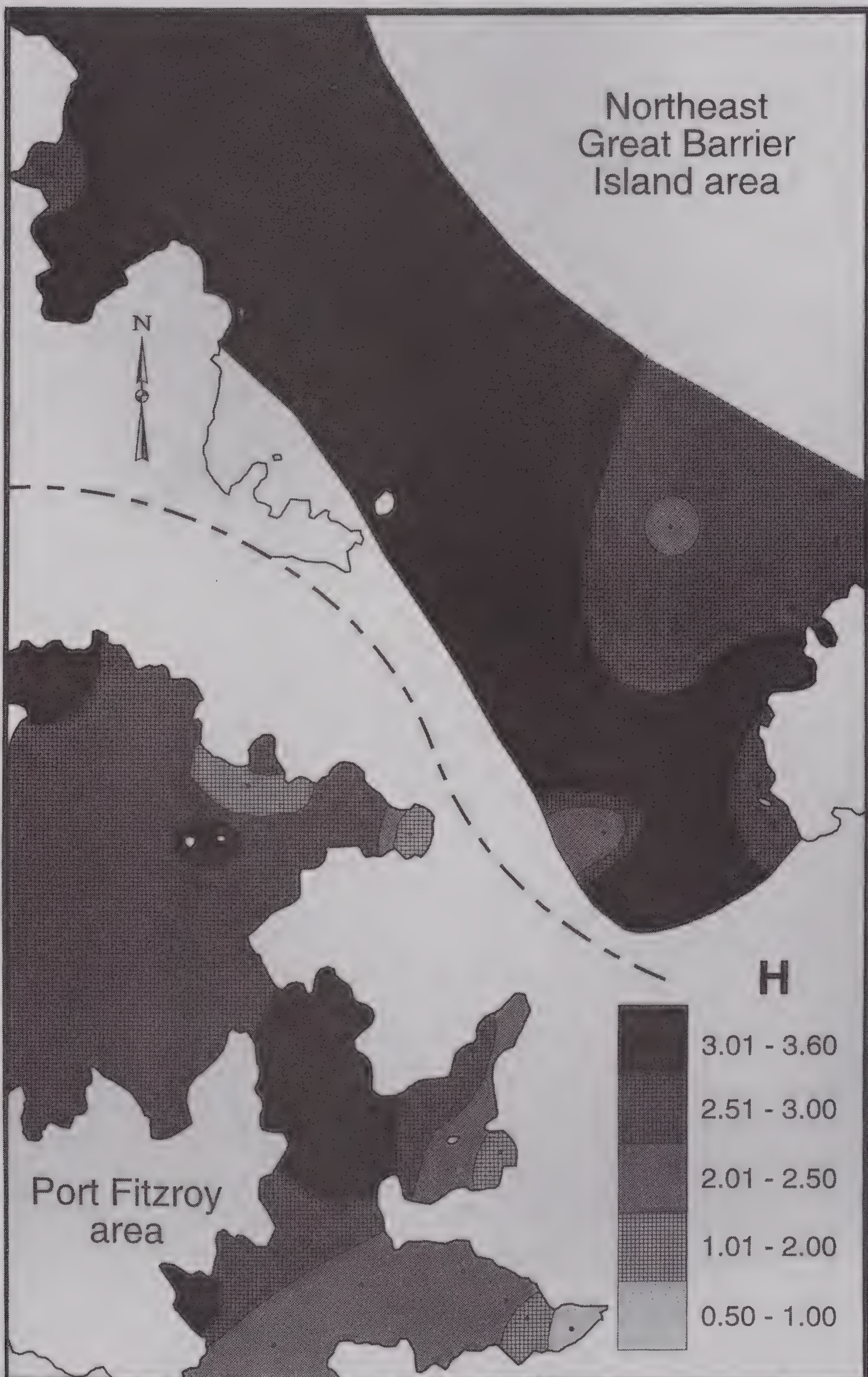


Fig. 40. Contoured map of Information Function, H, measure of species diversity in the two study areas around northern Great Barrier Island.

different associations is uncertain. There is however, in both the west and east an observable trend from associations inhabiting shallow, near shore habitats to those in quieter, deeper water. The trend in the west is:

A; 1 *Ammonia beccarii/Elphidium excavatum* - intertidal to 5 m;
B; 4 *Quinqueloculina seminula/Miliolinella subrotundata* - 2-17 m;
C; 2 *Elphidium charlottensis/Haynesina depressula* - 4-16 m;
D; 3 *Nonionella flemingi/Bolivina pseudoplicata* - 12-35 m.

The trend in the east is:

E,F; 5,6 *Gaudryina convexa/Discorbis dimidiatus* and *Discorbis dimidiatus/ Rosalina irregularis* - 1-33 m;
G2; 5 *Gaudryina convexa/Textularia proxispira* - 23-51 m;
G1,G3; 5 *Bulimina submarginata/Textularia ensis* - 34-58 m;
H; 7 *Bulimina submarginata/Hanzawaia bertheloti* - 50-68 m.

POST-MORTEM TRANSPORT OF FORAMINIFERAL TESTS

The distribution pattern of associations and dominant species indicates that current or wave transport of foraminiferal tests is not a major factor in influencing the foraminiferal sample and species associations around northern Great Barrier Island. The distribution maps of selected common benthic species (Figs 36-39) indicate that there is little post-mortem transport of the dominant characterising species in sample associations A, D and F and species asociations 1, 3 and 6, for they have relatively sharp boundaries to their distributions. The dominant characterising species in the other associations have more gradational boundaries to their distribution patterns. These may reflect the actual live distributional range of these species or it may be a result of post-mortem bottom current transport of tests spreading them away from their normal range.

Undoubtedly there is some post-mortem transport and winnowing of tests, especially in areas of strong currents in the entrances to Port Fitzroy and in places exposed to big swells and storms off northeast Great Barrier. For example the abundance of *Hanzawaia bertheloti* and *Bulimina submarginata* tests (characteristic of associations 7 and H) in the shallows of Rangiwhakaea Bay and as mappable tongues stretching into the shallows west of Rakitu Island (Fig. 39) is best explained by post-mortem inshore transport by northeast swells and currents.

PLANKTIC FORAMINIFERA (Fig. 41)

ASSOCIATIONS

Two distinctly different associations of planktic foraminiferal tests occur in sediments on either side of northern Great Barrier Island. On the more exposed northeast side, the planktic association is diverse in size range and taxonomic composition. It is dominated by *Globigerina falconensis* with subdominant *Globigerina quinqueloba* and *Globorotalia inflata. Globigerinoides ruber, Globigerina bulloides* and *Globigerinita glutinata* are also common. A further 10 species are present in low numbers (Appendix 1). The taxonomic composition, diversity and specimen size show some shoreward movement and input from the plankton of the open oceans off northeast Northland (Hayward 1983).

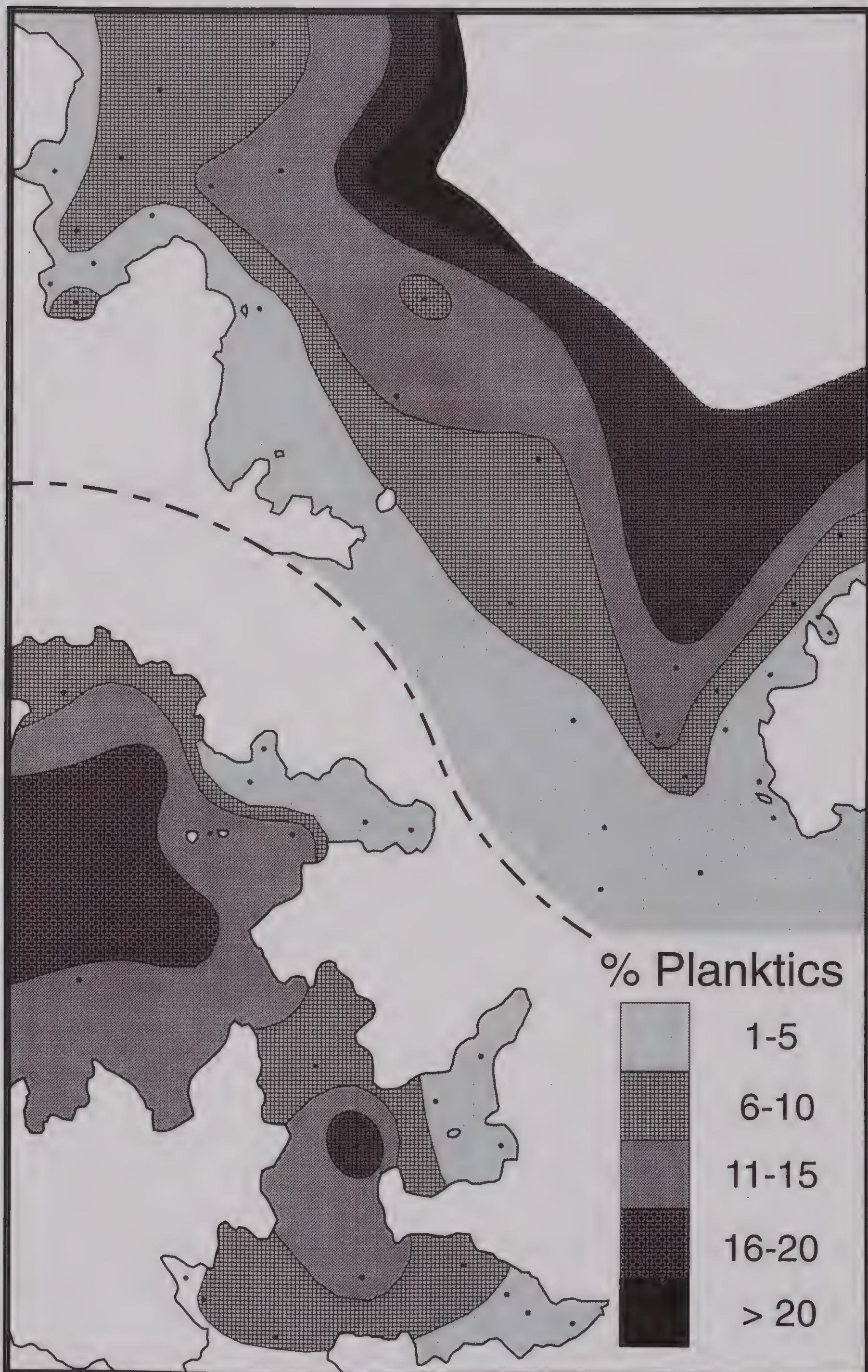


Fig. 41. Contoured map of planktic foraminiferal abundance in the two study areas around northern Great Barrier Island, expressed as a percentage of the total foraminiferal fauna.

The planktic association on the more sheltered northwest side is largely composed of small tests and is of low taxonomic diversity. It is dominated by *Globigerina falconensis* and *Globigerina quinqueloba,* with rare occurrences of only three other species. This composition and small specimen size is typical of nearshore neritic plankton faunas around most of New Zealand (Hayward 1983).

RELATIVE ABUNDANCE

Background relative abundances of planktic foraminiferal tests seem to be similar on both sides of northern Great Barrier Island, with planktics comprising 15-20% of the foraminiferal fauna in exposed situations on the northwest side (25-40 m depth, Port Abercrombie) and on the northeast side (40-70 m depth). In both areas the relative abundance of planktic tests progressively decreases to 0-5% as one moves into the shallows around the coast and in the bays. The shallow inner extremities of the arms of Ports Abercrombie and Fitzroy, for example, each have 2% or fewer planktics.

The single exception to this usual trend of decreasing planktic abundance with decreasing distance from land, occurs in Port Fitzroy. Here there is a slightly increased abundance of planktic tests (10-16%) within the 25-30 m deep basin of northern Port Fitzroy. This higher than normal relative abundance of planktic tests in an enclosed, sheltered nearshore situation is probably due to concentration of planktic tests carried in to the port by strong tidal currents through Fitzroy Passage. In the quieter waters of northern Port Fitzroy, many small planktic tests settle out of suspension and concentrate in the muddy sediment. A similar explanation is proposed for the even higher values in Port Pegasus, Stewart Island (Hayward *et al.* 1994).

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APPENDIX 1. Physical characteristics and planktic foraminiferal percentages of Great Barrier foraminiferal samples.

Stat.	Cat. No.[1]	Latitude	Longitude[2]	Depth[3]	%Plank.	H[4]	Sediment
Port Abercrombie/Port Fitzroy							
1	L2803	36° 8.65' S	175° 19.34' E	17	10	3.09	gravelly coarse sand
2	L2807	36° 8.98' S	175° 19.78' E	30	19	2.61	slightly gravelly mud
3	L2809	36° 9.00' S	175° 20.42' E	12	0	1.93	fine-medium sand
4	L2810	36° 8.88' S	175° 20.37' E	2	2	2.91	gravelly fine-medium sand
5	L2811	36° 9.25' S	175° 20.17' E	12	11	3.45	sandy gravel
6	L2812	36° 9.24' S	175° 20.52' E	24	11	2.85	slightly gravelly muddy fine sand
7	L2815	36° 9.18' S	175° 20.93' E	12	3	2.75	slightly gravelly muddy fine sand
8	L2816	36° 9.21' S	175° 21.11' E	2	0	1.41	fine sand
9	L2818	36° 9.60' S	175° 19.40' E	35	18	2.81	slightly gravelly mud
10	L2819	36° 9.81' S	175° 19.50' E	33	14	2.89	slightly gravelly mud
11	L2820	36° 9.60' S	175° 20.03' E	32	20	2.56	slightly gravelly mud
12	L2827	36° 10.12' S	175° 20.70' E	34	9	3.15	slightly,gravelly muddy fine sand
13	L2828	36° 10.48' S	175° 20.90' E	29	16	3.09	slightly gravelly muddy fine-medium sand
14	L2830	36° 10.18' S	175° 21.48' E	16	1	2.56	muddy fine sand
15	L2831	36° 9.98' S	175° 21.52' E	4	1	2.52	slightly gravelly muddy fine sand
16	L2832	36° 10.45' S	175° 21.58' E	LT	2	1.97	gravelly coarse sand
17	L2835	36° 10.98' S	175° 20.92' E	22	13	2.49	mud
18	L2837	36° 10.91' S	175° 21.40' E	17	8	2.30	mud
19	L2838	36° 11.02' S	175° 21.62' E	12	5	2.41	mud
20	L2840	36° 11.10' S	175° 21.75' E	5.5	3	1.24	muddy fine sand
21	L2841	36° 11.12' S	175° 21.97' E	MT	0	0.57	slightly gravelly medium-coarse sand
22	L2842	36° 11.02' S	175° 20.05' E	7	0	2.99	slightly gravelly medium-coarse sand
23	L2843	36° 11.08' S	175° 20.19' E	13	7	3.04	medium-fine sand
24	L2844	36° 11.22' S	175° 20.50' E	23	5	2.15	mud
North eastern Great Barrier							
25	F202061	36° 4.1' S	175° 25.8' E	56	8	3.13	slightly gravelly muddy fine sand
26	F202057	36° 4.3' S	175° 25.2' E	34	7	3.35	fine sand
27	F202055	36° 4.6' S	175° 24.9' E	28	8	3.17	fine sand
28	F202049	36° 4.7' S	175° 24.4' E	19	2	2.76	coarse sandy pebbly gravel
29	F202040	36° 4.8' S	175° 25.5' E	33	14	3.46	fine sand
30	F202054	36° 4.9' S	175° 25.2' E	22	3	3.31	fine sand
31	F202048	36° 5.1' S	175° 24.5' E	14	10	3.54	fine sand
32	F202045	36° 5.3' S	175° 24.6' E	9	2	3.26	fine sand
33	F202043	36° 5.5' S	175° 24.3' E	6	7	3.35	gravelly coarse sand
34	F202046	36° 5.6' S	175° 24.6' E	3	4	3.17	fine sand
35	F202041	36° 4.7' S	175° 25.9' E	47	10	3.47	slightly muddy fine sand
36	F202042	36° 4.7' S	175° 26.6' E	59	21	3.28	muddy fine sand
37	F202062	36° 5.5' S	175° 25.8' E	30	4	3.08	gravelly very coarse sand
38	F202060	36° 5.5' S	175° 26.8' E	51	4	3.32	slightly muddy fine sand
39	F202053	36° 6.1' S	175° 26.7' E	35	11	3.35	fine sand
40	F201866	36° 5.7' S	175° 28.2' E	68	19	2.71	muddy fine sand
41	F202052	36° 6.4' S	175° 27.6' E	53	9	3.40	slightly muddy fine sand
42	F201865	36° 6.4' S	175° 28.5' E	60	17	2.26	muddy fine sand
43	F202051	36° 7.2' S	175° 27.5' E	47	7	3.07	slightly gravelly coarse sand
44	F201857	36° 6.9' S	175° 28.4' E	50	16	2.96	fine sand

45	F201880	36° 6.9' S	175° 29.6' E	58	6	2.78	slightly muddy fine sand
46	F201870	36° 7.2' S	175° 29.4' E	51	5	2.91	slightly gravelly coarse sand
47	F201848	36° 7.4' S	175° 29.6' E	5	4	3.17	slightly muddy slightly gravelly very c. sand
48	F201851	36° 7.3' S	175° 29.5' E	9	2	2.79	slightly muddy slightly gravelly coarse sand
49	F201878	36° 7.5' S	175° 29.3' E	23	3	3.31	gravelly coarse sand
50	F201856	36° 7.5' S	175° 28.4' E	44	14	2.71	slightly muddy fine sand
51	F201854	36° 7.6' S	175° 28.8' E	45	9	3.02	slightly muddy gravelly very coarse sand
52	F201875	36° 7.7' S	175° 28.9' E	34	3	3.12	slightly muddy medium sand
53	F201874	36° 7.7' S	175° 28.4' E	36	11	3.03	slightly muddy fine sand
54	F201863	36° 7.8' S	175° 27.7' E	37	2	3.22	slightly gravelly coarse sand
55	F201873	36° 8.2' S	175° 28.6' E	27	7	3.48	fine sand
56	F201850	36° 8.2' S	175° 29.2' E	1	2	2.60	medium sand
57	F201853	36° 8.3' S	175° 29.3' E	12	4	2.78	slightly gravelly medium sand
58	F201860	36° 8.3' S	175° 28.1' E	28	1	2.34	slightly gravelly coarse sand
59	F201872	36° 8.5' S	175° 28.9' E	24	1	3.11	slightly sandy pebbly gravel
60	F201858	36° 8.8' S	175° 28.5' E	25	3	3.39	coarse sandy pebbly gravel

[1] F = Catalogue number of Micropaleontology Section, Institute of Geological and Nuclear Sciences Ltd, Lower Hutt. L = Catalogue number of Marine Departments, Auckland Institute and Museum.
[2] Hydrographic charts NZ 5225 (1:36,000) and NZ 531 (1:100,000).
[3] LT = low tide; MT = mid tide.
[4] H = Information function.

APPENDIX 2. List of foraminifera identified from Great Barrier Island. Asterisked species (*) were not recorded in the quantitative data, but identified from additional picks of rarer taxa.

BENTHIC SPECIES

Suborder Textulariina

*__Cribrostomoides jeffreysi__ (Williamson); Murray 1971, p. 23, pl. 4.
__Gaudryina convexa__ (Karrer); Hayward 1982a, fig. 6b. This paper fig. 4.
__Haplophragmoides canariensis__ (d'Orbigny); Loeblich & Tappan 1988, pl.49, figs 12-13.
__Haplophragmoides wilberti__ Andersen; Hayward & Hollis 1994, pl. 2, figs 4-6.
__Reophax arctica__ Brady; Hayward & Hollis 1994, pl. 1, figs 6-10.
__Reophax moniliforme__ Siddall; Hayward & Hollis 1994, pl. 1, figs 11-16.
__Reophax scorpiurus__ Montfort; emend. Bronnimann & Whittaker 1980, p. 260, figs 1-7, 12, 17 (see also Loeblich & Tappan 1988, p. 58, pl. 44, figs 1-3).
__Rotaliammina adaperta__ (Rhumbler); Wells 1985, p.588, figs 2-3, 10 (as *Trochammina*).
*__Rotaliammina__ sp.
*__Saccammina ?difflugiformis__ (Brady); Hoglund 1947, p. 53, pl. 4, fig. 18 (as *Proteonina*).
__Sigmoilopsis wanganuiensis__ Vella 1957, p. 20, pl. 4, figs 67-70.
__Sigmoilopsis finlayi__ Vella 1957, p. 20, pl. 4, figs 75, 76.
*__Sigmoilopsis__ sp.
__Siphonoaperta macbeathi__ Vella 1957, p. 19, pl. 4, figs 61, 62, 63.
*__?Siphonaperta__ sp.
__Siphotextularia blacki__ Vella 1957, p. 16, pl. 4, figs 53-54.
__Siphotextularia mestayerae__ Vella 1957, p. 17, pl. 4, figs 55-57.
*__Spiroplectammina__ cf. __biformis__ (Parker & Jones); Loeblich & Tappan 1988, pl. 119, figs 19-20.
__Technitella__ sp.
__Textularia__ cf. __conica__ d'Orbigny; Barker 1960, pl. 43, figs 13-14.
__Textularia earlandi__ (Parker); Hayward & Hollis 1994, pl. 3, figs 1-4.
__Textularia ensis__ Vella 1957, p. 16, pl. 3, figs 46-47. Hayward 1982a, fig. 6p. This paper fig. 5.
__Textularia fistulosa__ Brady; Hayward & Grace 1981, fig. 5a.
__Textularia proxispira__ Vella 1957, p. 15, pl. 3, figs 48, 52. This paper fig. 6.
__Textularia__ sp.
__Trochammina bartrami__ Hedley *et al.* 1967, p. 21, pl. 6, figs 2a-c, text-figs 9-10.
__Trochammina inflata__ (Montagu); Hayward & Hollis 1994, pl. 2, figs 10-11.
__Trochammina sorosa__ Parr 1950, p. 16, pl. 3, figs 46-47.
__Trochammina__ sp.

Suborder Miliolina

__Cyclogyra involvens__ (Reuss); Hedley *et al.* 1967, p. 24, text-fig. 16.
__Massilina__ cf. __milletti__ (Wiesner); Barker 1960, pl. 9, figs 9-10.
__Miliolinella labiosa__ (d'Orbigny); Hedley *et al.* 1967, p. 29, pl. 8, figs 2a-c.
__Miliolinella subrotundata__ (Montagu); Hayward *et al.* 1994, fig. 3E. This paper fig. 7.
*__Nevillina coronata__ (Millett); Brook *et al.* 1981, fig. 5a.
__Pyrgo anomala__ (Schlumberger); Vella 1957, p. 29, pl. 7, figs 135-136 (as *Biloculina*)
__Pyrgo comata__ (Brady); Barker 1960, pl. 3, fig. 9.
__Pyrgo depressa__ (d'Orbigny); Vella 1957, p. 29, pl. 7, figs 137, 140.
__Pyrgo__ aff. __ezo__ Asano; Vella 1957, p. 29, pl. 7, figs 138-139.
__Quinqueloculina agglutinans__ d'Orbigny; Hedley *et al.* 1965, p. 12, pl. 2, figs 7a-b.
__Quinqueloculina ?ariminensis__ d'Orbigny; Hayward 1982a, fig. 6k.
__Quinqueloculina auberiana__ d'Orbigny; Hedley *et al.* 1967, p. 25, pl. 8, figs 5a-c.
__Quinqueloculina bicornis__ (Walker & Jacob); Murray 1971, p. 57, pl. 20, figs 1-5.
__Quinqueloculina colleenae__ Vella 1957, p. 25, pl. 5, figs 86, 93. This paper fig. 8.

Quinqueloculina delicatula Vella 1957, p. 26, pl. 4, figs 77-79.
Quinqueloculina aff. ***lata*** Terquem; Murray 1971, pl. 23, figs 1-3.
Quinqueloculina neosigmoilinoides Kennett; Vella 1957, p. 24, pl. 6, figs 115-117 (as *Q. sigmoilinoides*).
Quinqueloculina parvaggluta Vella 1957, pl. 4; figs 71-73.
Quinqueloculina patagonica (d'Orbigny); Hedley *et al.* 1967, pl. 8, fig. 6.
Quinqueloculina seminula (Linnaeus); Hedley *et al.* 1965, p. 13, pl. 2, figs 8a-b. This paper fig. 9.
Quinqueloculina cf. ***semistriata*** d'Orbigny; McCulloch 1977, p.507, pl.219, figs 19-20.
Quinqueloculina suborbicularis d'Orbigny; Vella 1957, p. 23, pl. 6, figs 102-104. Hayward 1982a, fig. 6a.
Quinqueloculina tenagos Parker; Hedley *et al.* 1965, p. 27, pl. 9, figs 1A-C.
****Spiroloculina communis*** Cushman & Todd; Hedley *et al.* 1965, p. 13, pl. 2, figs 9a-c.
Spiroloculina disparilis Terquem; Vella 1957, p. 27, pl. 6, figs 122-123.
****Spiroloculina angulata*** Cushman; Hayward 1980, fig. 2.
****Spirosigmoilina tenuis*** (Czjzek); Barker 1960, pl. 10, figs 7, 8, 11 (as *Sigmiolina)*
Triloculina chrysostoma (Chapman); Vella 1957, p. 28, pl. 5, figs 97-99.
Triloculina tricarinata d'Orbigny; Barker 1960, pl. 3, fig. 17.
Triloculina trigonula (Lamarck); Boltovskoy *et al.* 1980, p. 52, pl. 33, figs 14-16.

Suborder Rotaliina
Acervulina inhaerens Schulze; Hedley *et al.* 1967, pl. 1, fig. 2.
Ammonia beccarii (Linnaeus); Hayward 1979, fig. 3a. This paper figs 2-13.
Amphicoryna cf. ***nebulosa*** (Ishizaki); Hayward & Buzas 1979, pl. 4, fig. 46.
Amphicoryna proxima (Silvestri); Barker 1960, pl. 64, fig. 15.
Amphicoryna scalaris (Batsch); Barker 1960, pl. 58, figs 28-31.
Anomalina spherica Finlay; Hayward *et al.* 1994, figs 3L-N. This paper fig. 14.
Astacolus neolatus Vella 1957, pl. 7, figs 143, 146-148.
Bolivina cf. ***arta*** MacFadyen; Hornibrook 1961, pl. 10, fig. 184 (as *B. lapsus*, see Hayward & Buzas 1979).
Bolivina compacta Sidebottom; Hedley *et al.* 1967, p. 30, pl. 9, fig. 3.
Bolivina pseudoplicata Heron-Allen & Earland; Hedley *et al.* 1967, pl. 9, fig. 4. This paper fig. 10.
Bolivina robusta Brady; Barker 1960, pl. 53, figs, 7-9.
Bolvina cf. ***seminuda*** Cushman; Parr 1950, pl. 12, fig. 17.
Bolivina spathulata (Williamson); Hedley *et al.* 1965, p. 21, pl. 6, fig. 23.
Bolivina cf. ***spinescens*** Cushman 1911, p. 47, fig. 7b.
Bolivina striatula Cushman; Boltovskoy *et al.* 1980, p. 18, pl. 3, figs 9-13. This paper fig. 11.
Bolivina subexcavata Cushman & Wickenden; Hayward & Grace 1981, p. 49, fig. 5c.
Bolivina cf. ***translucens*** Phleger & Parker; Boltovskoy *et al.* 1980, pl. 3, figs 18-21.
Bolivina sp.
Bulimina elongata d'Orbigny; Barker 1960, pl. 51, figs 1, 2.
Bulimina gibba Fornasini; Barker 1960, pl. 50, figs 1-4. This paper fig. 15.
Bulimina patagonica d'Orbigny; Boltovskoy *et al.* 1980, pl. 5, figs 13-17.
Bulimina submarginata Parr; Hayward 1982a, fig. 6m. This paper fig. 16.
Buliminella elegantissima (d'Orbigny); Loeblich & Tappan 1988, pl. 572.
Buliminoides madagascarensis (d'Orbigny); Hayward 1982a, fig. 6i.
Buliminoides williamsonianus (Brady); Hayward 1982a, fig. 6j.
Cancris oblongus (Williamson); Haynes 1973, pp. 145-147, text figs 27, nos 1-3, pl. 20, fig. 13.
* ***Carterina spiculotesta*** (Carter); Hayward 1980, figs 6-7.
Cassidulina carinata Silvestri; Eade 1967, p. 429, fig. 2, nos. 5-9. Hayward 1982a, fig. 6k.
****Chilostomella ovoidea*** Reuss; Loeblich & Tappan 1988; p. 625, pl. 701.
Cibicides corticatus Earland; Vella 1957, pl. 9, figs 195-197.
Cibicides cf. ***deliquatus*** Finlay; Hornibrook *et al.* 1989, p. 89, fig. 23, nos. 18a, b.
Cibicides marlboroughensis Vella 1957, p. 40, pl. 9, figs 189-191.

Cornuspira sp.
Cymbaloporetta bradyi (Cushman); Barker 1960, pl. 102, fig. 14.
****Dentalina subemaciata*** Parr 1950, p. 329, pl. 7, fig. 1.
****Dentalina mutsui*** Hada; Albani 1968, p. 23, fig. 78.
****Dentalina translucens*** Parr 1950, p. 328, pl. 11, fig. 25.
Discorbinella vitrevoluta (Hornibrook); Brook *et al.* 1981, fig. 5b.
Discorbis dimidiatus (Jones & Parker); Hedley *et al.* 1967, p. 33-36, pl. 1, fig. 4, pl. 10, figs 1-3, text-figs 28-43. This paper figs 17-18.
Dyocibicides sp. Vella 1957, p. 41, pl. 9, figs 198-200.
Earltheeia clarionensis McCulloch; Brook *et al.* 1981, fig. 5c.
Ehrenbergina aspinosa Parr; Eade 1967, fig. 7, nos 4-6, fig. 8, nos 1,2.
Ehrenbergina mestayeri Cushman; Eade 1967, fig. 8, nos 6,7.
Elphidium advenum f. ***depressulum*** Cushman; Hayward *et al.* 1994, fig. 3O.
Elphidium charlottensis (Vella) 1957, p. 38, pl. 9, figs 187, 188 (as *Elphidiononion*). This paper fig. 20.
Elphidium crispum (Linnaeus); Loeblich & Tappan 1988, p. 674, pls 786, 787.
Elphidium excavatum s.l. Cushman; Hayward & Hollis 1994, pl. 5, figs 6-8. This paper fig. 19.
Elphidium excavatum n.f. Hayward 1982a, fig. 5b (as *Elphidium oceanicum).*
Elphidium novozealandicum Cushman; Hayward *et al.* 1994, fig. 3P.
Epistominella vitrea Parker; Todd & Low 1981, p. 40 (in key), 3 figs. This paper figs 21-22.
Evolvocassidulina orientalis (Cushman); Hayward 1982a, fig. 6u.
Fissurina baccata (Heron-Allen & Earland 1922), p. 162, pl. 6, figs 15,16 (as *Lagena orbignyana* var. *baccata*).
Fissurina biumbonata McCulloch; Hayward & Grace 1981, p. 50, fig. 5d.
Fissurina claricurta McCulloch 1977, p. 95, pl. 58, fig. 16. Brook *et al.* 1981, fig. 5d.
Fissurina clathrata (Brady); Barker 1960, pl. 60, fig. 4.
Fissurina contusa Parr; Barker 1960, pl. 60, fig. 3. Brook *et al.* 1981, fig. 5e.
Fissurina contusa colomboensis McCulloch 1977, p. 97, pl. 64, fig. 5.
Fissurina cf. ***elliptica*** Seguenza; Boltovskoy *et al.* 1980, p. 32, pl. 15, figs 11-13.
Fissurina laevigata Reuss; Barker 1960, pl. 114, fig. 8.
Fissurina lucida (Williamson); Albani & Yassini 1989, p. 397, fig. 4E.
Fissurina cf. ***marginata*** (Montagu); Hayward & Buzas 1979, p. 57, pl. 16, fig. 207.
Fissurina marginatoperforata (Seguenza); Albani & Yassini 1989, p. 398, figs 6F-G.
****Fissurina orbignyana*** Seguenza; Hayward & Buzas 1979, p. 57, pl. 16, fig. 210.
****Fissurina quadrirevertens*** McCulloch; Brook *et al.* 1981, fig. 5f.
Fissurina semialata (Balkwill & Millett); Brook *et al.* 1981, fig. 5g.
Fissurina subovata (Parr); Parr 1950, pl. 10, figs 12-14.
Fursenkoina schreibersiana (Czjzek); Hayward & Buzas, 1979, p. 58, pl. 17, fig. 212.
Fursenkoina sp.
Gavelinopsis hamatus Vella 1957, p. 35, pl. 9, figs 177-180. Hayward 1982a, fig. 6t.
Gavelinopsis lobatulus (Parr); Hayward *et al.* 1994, fig. 4A. This paper fig. 23.
Glabratella margaritaceus (Earland); Earland 1933, p. 125, pl. 4, figs 23-25 (as *Discorbis*).
****Globobulimina notovata*** (Chapman); Barker 1960, pl. 50, fig. 13.
Globocassidulina canalisuturata Eade; Hayward 1982a, fig. 6n.
Globocassidulina minuta (Cushman); Eade 1967, fig. 5.2-3.
Globulina inaequalis Reuss; McCulloch 1977, p.182, pl.77, figs 4-5.
Guttulina bartschi Cushman & Ozawa 1930, pl.1, fig.10.
Guttulina irregularis (d'Orbigny); Cushman & Ozawa 1930, p. 25, pl. 3, figs 3, 4.
Guttulina yabei Cushman & Ozawa 1929, p. 68, pl. 13, fig. 2, pl. 14, fig. 6.
Gypsina vesicularis (Parker & Jones); Barker 1960, pl. 101, figs 9-12.
Gyroidina sp.
Hanzawaia bertheloti (d'Orbigny); Hayward 1982a, fig. 6q-r. This paper fig. 24.

Hanzawaia complanata (Sidebottom); Hornibrook 1961, pl. 27, fig. 532 (as *Discorbinella*).
*****Hanzawaia lepida*** (Hornibrook 1961), p. 117, pl.15, figs 306, 307, 317 (as *Discorbinella*).
Hanzawaia sp.
Haynesina depressula (Walker & Jacob); Hayward & Hollis 1994, pl. 5, figs 13-16. This paper fig. 25.
*****Heronallenia pulvinulinoides*** (Cushman) 1915, pl. 6, fig. 3 (as *Discorbis*).
*****Hoeglundina elegans*** (d'Orbigny); Loeblich & Tappan 1988, pl. 478, figs 1-5.
Laevidentalina communis (d'Orbigny); Barker 1960, pl. 62, figs 21, 22 (as *Dentalina*).
Laevidentalina filiformis (d'Orbigny); Hornibrook 1961, pl. 6, fig. 92 (as *Rotalia*).
Lagena cf. ***alticostatiformis*** McCulloch 1977, p. 26, pl. 53, figs 5, 6.
*****Lagena crenata*** Parker & Jones; Barker 1960, pl. 57, figs 15, 21.
*****Lagena doveyensis*** (Haynes); Albani & Yassini 1989, figs 2H-I.
*****Lagena flatulenta*** Loeblich & Tappan; Albani 1968, p. 24, fig. 86.
Lagena cf. ***hispida*** Reuss; Barker 1960, pl. 57, fig. 2.
Lagena lyelli (Seguenza); Boltovskoy *et al.* 1980, pl. 20, figs 15-17 (as *Lagena sulcata* var. *lyellii*)
*****Lagena*** cf. ***mccullochi*** Albani & Yassini 1989, figs 2O-P.
*****Lagena nebulosa*** Cushman; Barker 1960 pl. 56, fig. 12.
Lagena spiratiformis McCulloch; Albani & Yassini 1989, figs 2V-W.
Lagena sulcata spicata Cushman & McCulloch; Barker 1960, pl. 58, figs 4-6.
Lagena cf. ***striata strumosa*** Albani & Yassini 1989, fig. 2U
*****Lagenosolenia sigmoidella timmsensis*** (Cushman & Gray). McCulloch 1977, p.72, pl.51, figs 10-14.
*****Lagenosolenia tubulifera*** (Egger).
Lagenosolenia sp.
*****Laticarinina coronata*** (Heron-Allen & Earland); Hornibrook 1961, pl. 15, figs 310, 311, 318.
*****Lenticulina asterizans*** Parr 1950, p. 322, pl. 11, figs 9-10.
Lenticulina australis Parr 1950, p. 322, pl. 11, figs 7, 8.
*****Lenticulina iota*** (Cushman); Cushman 1923, p. 111, pl. 29, fig. 2, pl. 30, fig. 1 (as *Robulus*).
Loxostomum karrerianum (Brady); Hornibrook 1968, p. 77, fig. 14.
*****Loxostomum limbatum costulatum*** (Cushman); Hayward 1980, fig. 3.
*****Mychostomina revertens*** (Rhumbler); Brook *et al.* 1981, fig. 5i.
Mychostomina sp.
Neoconorbina pacifica Hofker; Hayward 1982a, fig 6g-h.
*****Neoconorbina*** n.sp.
Nodosaria sp.
Nonion sp.
Nonionella flemingi (Vella); Hayward *et al.* 1994, fig. 4C. This paper fig. 26.
*****Nonionella magnalingua*** Finlay; Hornibrook 1961, pl.12, figs 226, 232-233.
Nonionella turgida (Williamson); Barker 1960, pl. 109, figs 17-19.
Notorotalia depressa Vella 1957, p. 47, pl. 1, figs 13, 19, 20. Hayward 1982a, fig. 5x.
Notorotalia olsoni Vella 1957, p. 50, pl. 2, figs 23-24. Hayward 1982a, fig. 5u-v. This paper fig. 27-28.
Oolina globosa (Montagu); Hayward & Buzas 1979, p. 68, pl. 23, figs 284-285.
Oolina hexagona (Williamson); Hayward & Buzas 1979, p. 68, pl. 23, fig. 286.
*****Oolina lineata*** (Williamson); Barker 1960, pl. 57, fig. 13.
Oolina melo d'Orbigny; Barker 1960, pl. 58, figs 28-31.
Oolina scalariformis McCulloch 1977, p. 84, pl. 54, fig. 20.
Oolina tasmanica Parr 1950, p. 303, pl. 8, fig. 4.
Oridorsalis umbonatus (Reuss); Hayward & Buzas 1979, p. 68, pl. 24, figs 295-296.
Palliolatella cf. ***aradisiformis*** Albani & Yassini 1989, fig. 5F.
Palliolatella lacunata paucialveolata Albani & Yassini 1989, figs 5L-M.
Palliolatella sp.
Patellina corrugata Williamson; Hornibrook 1961, p. 97, pl. 13, fig. 250.
Patellinella inconspicua (Brady); Hayward 1982a, fig. 5q.
Pileolina calcarata (Heron-Allen & Earland); Hayward 1982a, fig. 5j-k.

Pileolina harmeri (Heron-Allen & Earland); Hayward 1982a, fig. 6e-f.
Pileolina patelliformis (Brady); Hayward 1982a, fig. 5n-o.
Pileolina radiata Vella 1957, p. 36, pl. 8, figs 170, 171. Hayward 1982a, figs 5h-i.
Pileolina zealandica Vella; Hayward 1982a, fig. 5l-m.
Planodiscorbis rarescens (Brady); Barker 1960, pl. 90, figs 2-3.
Planoglabratella opercularis (d'Orbigny); Hayward 1982a, fig. 6c-d.
Planorbulina acervalis Brady; Barker 1960, pl. 92, fig. 4.
Planulinoides planoconcava (Chapman, Parr & Collins); Parr 1932, pl. 22, figs 34a-c (as *Planulina biconcava* var. *planoconcava).*
****Procerolagena crassimplicata*** Albani & Yassini 1989, fig. 3A.
Procerolagena cylindrocostata Albani & Yassini 1989, fig. 3D.
****Procerolagena distoma margaritifera*** (Parker & Jones); Albani & Yassini 1989, figs 3B-C.
****Procerolagena elongata*** (Ehrenberg); Albani & Yassini 1989, fig. 3H.
Procerolagena sp.
Rectobolivina collumellaris (Brady); Barker 1960, pl. 75, figs 15-17.
Rosalina bradyi (Cushman); Hayward 1982a, fig. 5y. This paper fig. 29-30.
Rosalina irregularis (Rhumbler); Hedley *et al.* 1967, pl. 11, fig. 3. Hayward 1982a, fig. 6s. This paper fig. 31.
Rosalina paupereques Vella 1957, p. 35, pl. 9, figs 181-182.
****Rugidia simplex*** Collins; Hayward & Grace 1981, p. 50, fig. 5g.
****Saracenaria latifrons*** (Brady); Barker 1960, pl. 113, fig. 11.
Sigmavirgulina tortuosa (Brady); Hayward 1980, fig. 5.
Sigmoidella elegantissima (Parker & Jones); Barker 1960, pl. 72, fig. 12.
****Sigmoidella kagaensis*** Cushman & Ozawa; Loeblich & Tappan 1988, pl. 49, figs 3-7.
Sigmomorphina lacrimosa Vella 1957, p. 31, pl. 8, figs 149-151.
Siphouvigerina glabra Millett; Hayward & Triggs 1994, fig. 4, no. 3. This paper fig. 32.
Siphouvigerina interrupta (Brady); Barker 1960, pl. 75, figs 12-14 (as *Neouvigerina*).
Siphouvigerina vadescens (Cushman); Vella 1963, pl. 2, fig. 17.
Sphaeroidina bulloides d'Orbigny; Barker 1960, pl. 84, figs 1-7.
****Spirillina denticulina*** Brady; Barker 1960, pl. 85, fig, 17.
Spirillina vivipara Ehrenberg; Barker 1960, pl. 85, figs 1-4.
****Spirillina*** sp.
Svartkina australiensis (Chapman, Parr & Collins); Brook *et al.* 1981, fig. 5j.
****Trifarina carinata bradyana*** (Cushman) 1932, p. 45, pl. 6, figs 9-10.
Trifarina n.sp.
****Uvigerina peregrina*** Cushman; Barker 1960, pl. 74, figs 11, 12.
****Vaginulina vertebralis*** Parr 1932, p. 221, pl. 22, fig. 42.
Virgulopsis turris (Heron-Allen & Earland); Hayward 1982a, fig. 5c.
Zeaflorilus parri (Cushman); Hayward & Triggs 1994, fig. 4, nos. 16-17.

PLANKTIC SPECIES

Globigerina bulloides d'Orbigny; Hayward 1983, p. 64, figs 2C-E.
Globigerina falconensis Blow; Hayward 1983, p. 64, figs 2I-K.
Globigerina quinqueloba Natland; Hayward 1983, p. 64, figs 2O-Q.
Globigerinella aequilateralis (Brady); Hayward 1983, p. 49, figs 3A-C.
Globigerinita glutinata (Egger); Hayward 1983, p. 70, figs 3F-H.
Globogerinoides ruber (d'Orbigny); Hayward 1983, p. 70, figs 3N-O.
****Globogerinoides sacculifer*** (Brady); Hayward 1983, p. 70, figs 3P-R.
Globorotalia crassula Cushman & Stewart; Hayward 1983, p. 70, figs 4D-F.
Globorotalia hirsuta (d'Orbigny); Hayward 1983, p. 70, figs 4G-I.
Globorotalia inflata (d'Orbigny); Hayward 1983, p. 70, figs 4J-L

Globorotalia scitula (Brady); Hayward 1983, p. 70, figs 4M-O.
Globorotalia truncatulinoides (d'Orbigny); Hayward 1983, p. 71, figs 4P-R.
Neogloboquadrina dutertrei (d'Orbigny); Hayward 1983, p. 71, figs 5D-F.
Neogloboquadrina pachyderma (Ehrenberg); Hayward 1983, p. 71, figs 5G-I.
****Orbulina universa*** d'Orbigny; Hayward 1983, p. 70, fig 5J.
Pulleniatina obliquiloculata (Parker & Jones); Hayward 1983, p. 71, figs 5K-M.

APPENDIX 3. Main characterising species of the eight benthic foraminiferal associations recognised around northern Great Barrier Island. Species are arranged in order of decreasing Association Scores (Ass.Sc.) calculated from each species abundance (Abund.), fidelity (Fid.), persistence (Pers.), dominance (Dom.) and relative abundance (Rel.) within each association (see text for explanation).

	Dom.	Pers.	Fid.	Abund.	Rel.	Ass.Sc.
ASSOCIATION A *Ammonia beccarii/Elphidium excavatum*						
Stns. 8,16,20,21 = 4						
Ammonia beccarii	10.0	1.00	0.82	62.3	57.0	68.2
Elphidium excavatum s.l.	6.6	0.75	0.68	15.0	13.8	27.4
Haynesina depressula	6.4	0.75	0.02	7.3	3.8	15.2
ASSOCIATION B *Quinqueloculina seminula/Miliolinella subrotundata*						
Stns. 1,4,5,47 = 4						
Quinqueloculina seminula	8.0	1.00	0.25	9.5	4.9	21.4
Miliolinella subrotundata	7.3	1.00	0.33	7.8	4.8	20.4
Elphidium charlottensis	5.8	1.00	0.25	9.3	3.9	18.0
Bolivina pseudoplicata	4.3	1.00	0.55	6.3	4.0	17.6
Pileolina zelandica	4.5	1.00	0.50	4.8	3.2	16.6
Haynesina depressulus	5.0	1.00	0.29	5.0	1.5	15.0
Oolina melo	3.0	0.75	0.25	3.5	2.3	10.9
Rosalina bradyi	3.5	0.75	0.20	3.3	1.9	10.8
Gavelinopsis lobatulus	4.0	0.75	0.07	4.3	0.4	10.4
Notorotalia olsoni	4.0	0.75	0.02	4.5	1.1	10.3
ASSOCIATION C *Elphidium charlottensis/Haynesina depressula*						
Stns. 3,7,14,15,22,23 = 6						
Elphidium charlottensis	8.2	1.00	0.26	17.8	12.4	27.8
Haynesina depressula	7.7	1.00	0.30	16.2	12.7	26.8
Ammonia beccarii	5.5	1.00	0.85	7.7	2.2	21.5
Notorotalia olsoni	6.7	1.00	0.30	9.7	6.3	20.7
Bulimina gibba	3.0	0.83	0.61	3.3	2.5	14.0
Bolivina compacta	3.3	0.67	0.19	3.7	2.5	10.6
Quinqueloculina seminula	4.0	0.67	-0.03	4.8	0.2	9.4
ASSOCIATION D *Nonionella flemingi/Bolivina pseudoplicata*						
Stns. 2,6,9,10,11,12,13,17,18,19,24 = 11						
Nonionella flemingi	8.9	1.00	0.82	21.5	16.9	36.1
Bolivina pseudoplicata	5.9	0.82	0.41	8.0	5.7	19.0
Elphidium charlottensis	7.1	0.91	0.20	8.0	2.6	18.1
Epistominella vitrea	4.5	0.73	0.51	6.6	4.8	16.8
Bulimina submarginata	6.5	0.82	0.00	10.3	3.3	16.6
Bolivina striatula	3.0	0.82	0.68	3.5	2.7	16.4
Notorotalia olsoni	4.3	0.82	0.11	5.3	1.9	12.2

Siphouvigerina glabra	3.2	0.91	0.81	3.1	2.3	12.0
Haynesina depressula	2.7	1.00	0.33	3.6	0.1	11.5

ASSOCIATION E *Gaudryina convexa/Discorbis dimidiatus*
Stns. 56,57,58 = 3

Gaudryina convexa	9.7	1.00	0.46	22.7	18.7	35.3
Discorbis dimidiatus	6.3	1.00	0.53	16.0	13.5	27.2
Quinqueloculina colleenae	7.7	1.00	0.61	7.3	6.3	23.3
Dyocibicides sp.	6.7	1.00	0.46	6.7	4.9	20.2
Quinqueloculina seminula	7.7	1.00	0.25	8.0	3.4	19.4
Miliolinella subrotundata	3.0	1.00	0.33	3.3	0.3	11.8

ASSOCIATION F *Discorbis dimidiatus/Rosalina irregularis*
Stns. 27,29,30,31,32,33,34,48 = 8

Discorbis dimidiatus	6.2	1.00	0.58	7.0	4.5	20.6
Rosalina irregularis	5.5	0.88	0.57	7.1	5.3	19.5
Elphidium charlottensis	4.8	1.00	0.25	7.0	1.6	15.4
Gavelinopsis lobatulus	6.1	0.88	0.21	5.4	1.5	15.4
Rosalina bradyi	3.6	1.00	0.50	3.8	2.4	14.8
Quinqueloculina seminula	3.9	1.00	0.27	6.9	2.3	14.6
Miliolinella subrotundata	4.5	1.00	0.37	4.0	1.0	14.4
Gaudryina convexa	3.4	1.00	0.50	3.3	-0.7	13.3
Elphidium excavatum n.f.	2.1	0.63	0.48	2.3	1.8	10.4

ASSOCIATION G *Gaudryina convexa/Bulimina submarginata*
Stns. 25,26,35,37,38,39,41,43,45,46,49,50,51,52,53,54,55,59,60 = 19

Gaudryina convexa	5.2	0.95	0.56	7.2	3.2	18.7
Bulimina submarginata	7.1	0.95	0.19	8.4	1.4	18.0
Textularia ensis	4.6	0.79	0.47	5.9	3.4	16.0
Quinqueloculina seminula	5.4	1.00	0.34	5.5	0.9	15.9
Gavelinopsis lobatulus	4.9	1.00	0.41	5.1	1.2	15.8
Textularia proxispira	3.1	0.84	0.72	4.1	2.6	15.1
Cibicides marlboroughensis	2.8	0.95	0.58	3.7	1.9	14.8
Dyocibicides sp.	3.4	0.89	0.48	3.5	1.7	13.6
Miliolinella subrotundata	2.9	0.89	0.30	3.8	0.8	11.4

Subassociation G1 *Quinqueloculina seminula/Bulimina submarginata*
Stns. 25,37,38,39,41,43 = 6

Quinqueloculina seminula	8.7	1.00	0.26	8.3	3.7	21.4
Bulimina submarginata	7.3	1.00	0.20	7.8	0.8	18.0
Gavelinopsis lobatulus	6.3	1.00	0.33	6.2	2.3	17.6
Quinqueloculina parvaggluta	5.0	1.00	0.41	4.7	3.2	16.4
Cibicides marlboroughensis	3.8	1.00	0.50	4.8	3.0	15.6
Notorotalia olsoni	4.2	1.00	0.30	5.0	1.6	14.2
Bolivina spathulata	3.2	1.00	0.48	2.7	1.2	13.3
Hanzawaia bertheloti	3.5	0.83	0.39	3.7	2.2	13.0
Textularia ensis	3.3	0.83	0.40	3.0	0.5	12.0
Gaudryina convexa	3.0	0.83	0.29	5.0	1.0	11.8

Subassociation G2 *Gaudryina convexa/Textularia proxispira*
Stns. 46,49,52,54,55,59,60 = 7

Gaudryina convexa	7.6	1.00	0.51	10.6	6.6	24.0
Textularia proxispira	4.3	1.00	0.58	5.0	4.0	17.3
Quinqueloculina seminula	6.4	1.00	0.26	6.4	1.8	17.1
Pileolina zelandica	4.3	1.00	0.53	4.6	3.0	16.4
Dyocibicides sp.	4.0	1.00	0.49	4.3	2.5	15.4
Cibicides marlboroughensis	3.1	1.00	0.51	3.7	1.9	14.0
Gavelinopsis lobatulus	3.6	1.00	0.34	4.1	0.2	12.9
Textularia ensis	3.7	0.71	0.29	3.7	1.2	11.6
Bulimina submarginata	4.9	0.86	0.05	5.0	-2.0	11.3
Miliolinella subrotundata	2.3	1.00	0.36	3.4	0.4	11.2

Subassociation G3 *Bulimina submarginata/Textularia ensis*
Stns. 26,35,45,50,51,53 = 6

Bulimina submarginata	9.3	1.00	0.20	13.0	6.0	24.4
Textularia ensis	6.8	0.83	0.41	11.3	8.8	22.5
Miliolinella subrotundata	5.8	1.00	0.35	6.5	3.5	17.7
Gaudryina convexa	4.7	1.00	0.48	5.5	1.5	16.4
Textularia proxispira	4.0	0.83	0.53	5.5	4.0	16.1
Gavelinopsis lobatulus	5.0	1.00	0.33	5.2	1.3	15.3
Dyocibicides sp.	4.2	0.83	0.29	4.0	2.2	13.2

ASSOCIATION H *Bulimina submarginata/Hanzawaia bertheloti*
Stns. 36,40,42,44 = 4

Bulimina submarginata	8.3	1.00	0.20	26.8	19.8	33.7
Hanzawaia bertheloti	7.5	1.00	0.55	8.5	7.0	23.4
Anomalina spherica	6.8	1.00	0.68	5.8	3.9	21.4
Gavelinopsis lobatulus	8.5	1.00	0.32	7.5	3.6	21.2
Textularia ensis	3.5	0.75	0.29	3.8	1.3	11.6